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FLORA W. PATTERSON.

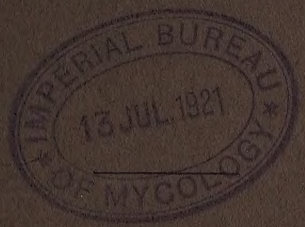
JULY, 1915 MEMOIR No. 8

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
OF THE COLLEGE OF AGRICULTURE

A BACTERIAL DISEASE OF STONE FRUITS

By F. M. ROLFS

FORMERLY OF THE DEPARTMENT OF PLANT PATHOLOGY, CORNELL UNIVERSITY
NOW PROFESSOR OF BACTERIOLOGY, CLEMSON COLLEGE, SOUTH CAROLINA



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CONTENTS

PAGE

Host considerations 381
The disease 381
Names 381
Historical 381
Geographical distribution 382
Economic importance 383
Symptoms 384
On the leaves 384
On the twigs 393
On the fruit 394
Etiology 394
Historical 394
Nomenclature 395
Pathogenicity 396
Morphology 398
Cultural characters 399
Life history 413
Inoculation 413
Incubation 418
Infection 419
Effect of environmental factors 421
Varietal susceptibility 422
Control 427
Exclusion 427
Eradication 428
Protection 429
Spraying 429
Cultivation 431
Immunization 434
Recommendations for control 434
Literature cited 435

A BACTERIAL DISEASE OF STONE FRUITS

A BACTERIAL DISEASE OF STONE FRUITS[1]

F. M. Rolfs

HOST CONSIDERATIONS

Cultivated varieties of the apricot (*Prunus armeniaca*), the nectarine (*Prunus persica* var. *necturina*), the peach (*Prunus persica*), and the plum (*Prunus domestica*, *Prunus americana*, and others), are known to be affected by the bacterial disease discussed herein. It will be noted that the hosts are closely related.

THE DISEASE

NAMES

The disease on the foliage during its early development or in cases of slight infection is known as *bacterial leaf spot;* in more advanced stages or in more serious outbreaks it is termed *bacterial shot hole.* On the fruit it is sometimes referred to as *black spot*, the growers, however, more commonly speaking of it as *bacterial crack.* The disease on the young twigs has received the names *black spot* and *black tip*, and when open perennial wounds are formed on the branches these are called *bacterial cankers.*

HISTORICAL

The disease is apparently of American origin, it having been found, so far as is known, only in the United States. During the past nine or ten years fruit growers in various sections of the country have called attention to a shot-hole disease of peach and plum foliage, which in wet seasons has in many cases caused premature defoliation. O'Gara (Rorer, 1909)[2] reports a shot-hole condition of peach foliage prevalent in Georgia, and suggests that it is caused by a bacterial organism. Smith (1903) calls attention to a bacterial disease of Japanese varieties of plum in central Michigan, which appears as a shot hole of the leaves and a black spot of the fruit. Clinton (1904) describes a leaf spot on peach in Connecticut, which he attributes to a bacterial organism. Heald (1906) discusses a disease, apparently of the same nature, found in Nebraska on the twigs

[1] Also presented to the Faculty of the Graduate School of Cornell University, June, 1913, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

Author's Acknowledgments.—The writer wishes to acknowledge his indebtedness to Professors Whetzel and Reddick, of the Department of Plant Pathology, New York State College of Agriculture, for many helpful criticisms and suggestions; and to Director Paul Evans, of the Missouri State Fruit Experiment Station, for his support and cooperation, which made it possible to undertake and complete the work.

[2] Dates refer to literature cited, page 435.

and branches of Wickson and Whitaker varieties of plum. Jackson (1907) reports a similar disease from Delaware, and states that considerable injury results to the plum orchards in that State. Smith (1905 b, figs. 11, 12, 15, 70, 72, pl. 19) gives diagrams of sections through diseased plum leaves and fruit tissue, and illustrations of diseased plum fruit. Rorer (1909) records a detailed study of the disease on leaves, twigs, and fruits of peach. Smith (1911) discusses the disease on plum leaves and fruits, and gives illustrations of diseased plum fruits as well as sections through diseased fruit tissue. Heald and Wolf (1912) report the occurrence of a bacterial canker on plum at San Antonio, Texas. Lewis (1912) describes a bacterial canker on plum twigs and records the results of several inoculation experiments. He gives illustrations of cankers on twigs four and six years of age.

The disease was first brought to the attention of the writer in 1904, when he was Botanist and Horticulturist at the University of Florida. Many letters were received from fruit growers in northern Florida and southern Georgia, complaining of a shot-hole condition of peach and plum leaves accompanied by considerable premature defoliation. The foliage of the different varieties of peach and plum trees in the university horticultural orchard also developed the shot-hole condition, and in most cases fell prematurely. Other duties prevented the writer from undertaking extensive investigation of the problem at that time. However, on taking up work at the Missouri State Fruit Experiment Station in 1906, he found that the blackened areas, so common on the peach twigs in northern Florida in 1905, were even more abundant on the peach and plum twigs in Missouri. Additional observations have brought out the fact that the disease is more or less injurious also to the apricot and the nectarine.

GEOGRAPHICAL DISTRIBUTION

It is not easy to obtain information as to the distribution of this disease, since a bibliography of the literature relating to shot-hole injury of stone fruits shows that the injury is usually attributed to the work of fungi. This is not surprising, as lesions resulting from various causes resemble one another so closely that it is often impossible to determine exactly the causal factor without the aid of a microscope, and it is not always possible even with a microscope. The disease has been reported by investigators as occurring in Arkansas, Connecticut, Delaware, Georgia,

Michigan, Nebraska, and Texas. Diseased material has been obtained by the writer from Alabama, Arkansas, Florida, Georgia, Illinois, Iowa, Kansas, Michigan, Missouri, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, and Texas.

ECONOMIC IMPORTANCE

Bacterial leaf spot, or shot-hole as it is usually called, is one of the chief foliage diseases of stone fruits in the humid districts of the South. It occasionally becomes more or less aggressive also in some sections of the northern and eastern States. Its importance varies from year to year, there being an abundance in wet seasons and little in dry seasons. The disease appears to be more severe in warm, humid regions than in cool, dry sections. In southern Missouri its economic importance has kept pace with the growth of the peach industry, and it is now one of the most difficult diseases with which the fruit grower has to contend. Its attacks on the plum have made it practically impossible to grow certain varieties of Japanese plums on a commercial scale. The fruit of some varieties of apricot and nectarine also are injured more or less by the disease, but since apricots and nectarines are not extensively grown in Missouri the disease on these fruits has not attracted much attention.

In different parts of Missouri, during 1908 and 1909, a record was made of the amount of infected fruit in diseased Elberta peach orchards, in order to determine the extent of the injury due to this disease. It was found that from 1 to 10 per cent of the fruit was infected in orchards well cared for, and from 25 to 75 per cent in orchards poorly cared for. The lesions on the fruit are in many cases not sufficiently prominent to mar its appearance greatly, but the larger proportion of such fruit is graded as "seconds." None of the fruit holds up well in shipping, and in some cases it is completely destroyed by various rot-producing organisms before being placed on the market.

It is especially difficult to obtain reliable figures on the loss due to this disease, since the loss is not confined to the direct effect on the fruit but must include also the influence of the diseased foliage on the general vigor of the tree. Severe outbreaks soon impair the efficiency of the foliage, and if they occur early in the season they reduce the size and greatly lower the quality of the fruit. Severe foliage injury also has a marked influence on the formation of fruit buds, and trees that have their leaves

injured early in the season usually carry a very light crop of fruit the following year. Young trees are usually more affected than those six or seven years old, and badly diseased young trees soon become stunted and in some cases permanently injured.

SYMPTOMS

The disease affects the leaves, twigs, and fruit in a characteristic manner. It develops on twigs and shoots of only the current year's growth, but the wounds on the twigs often persist as open perennial cankers.

The very common fungous disease of apricot and plum foliage due to *Cylindrosporium padi* is similar in its symptoms to bacterial leaf spot, but usually can be distinguished from the latter by the white downy growth on the lower surface of the spot. Pierce (1894) reports a similar disease on almond foliage in California due to the work of *Cercospora circumscissa*. There is also a leaf spot of unknown cause which is constantly associated with peach and plum rosette. Spray mixtures and other toxic substances applied to the leaves often produce an injury which is difficult, without the aid of a microscope, to distinguish from bacterial leaf spot. Care must be taken not to confuse the lesions due to these various agents.

On the leaves

The first evidence of the disease on the leaves is the appearance of small gray specks (Fig. 59), which become somewhat angular in form and soon take on a water-soaked appearance. They later become brown or purplish brown, in some cases scarlet, and finally change to dark brown. The spots measure from one to five millimeters in diameter and when numerous they coalesce, so that large areas of the leaf may be involved. A more or less circular diseased area is finally separated by a line of cleavage from the healthy tissue, the injured tissue within this area promptly contracting, drying, and falling out. This gives the leaf the shot-hole appearance. On the plum, in some cases, after the disease has apparently run its course and the spot is well formed, a second and even a third period of invasion may follow and an area one-half inch or more in diameter may develop from a single spot. Leaves that are badly diseased soon fall to the ground. It is not unusual for an infected tree to lose from fifteen to twenty-five per cent of its leaves by August, and in the more extreme cases as high as seventy-five per cent, or even more, of the leaves

Fig. 59.—*Elberta peach leaves inoculated with pure cultures of Bacterium Pruni. The growth from a seven-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and applied to the leaves by dipping the fingers into the water and then rubbing the leaf between the thumb and the fingers. Inoculations were made on July 16, 1912, and the photograph was taken on August 28, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Inoculated with a pure culture obtained from a peach twig
d, Inoculated with a pure culture obtained from a plum twig
e, Check. Sterile water was applied to the leaf

Fig. 60.—*Arp Beauty peach tree showing defoliation due to the work of Bacterium Pruni. Most of the leaves that formed before July 1, 1909, have fallen. All leaves still on the tree are more or less injured. (Photograph made on September 6, 1909)*

Fig. 61.—*Elberta peach twigs inoculated with pure cultures of Bacterium Pruni. The growth from an eight-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water. Each twig was inoculated at four points by inserting the point of a hypodermic needle just below the cuticle and forcing the water containing the organism into the tissues. Inoculations were made on June 25, 1912, and the photograph was taken on August 20, 1912*

a. Check. Sterile water was used
b and c, Inoculated with a pure culture obtained from an apricot twig
d, Inoculated with a pure culture obtained from a nectarine twig
e, Inoculated with a pure culture obtained from a peach twig
f, Inoculated with a pure culture obtained from a plum twig

Fig. 62.—*Elberta peach twigs, leaves, and fruit, showing injury by Bacterium Pruni. The black tips of the twigs are to be noted particularly. (Photograph made on August 15, 1909)*

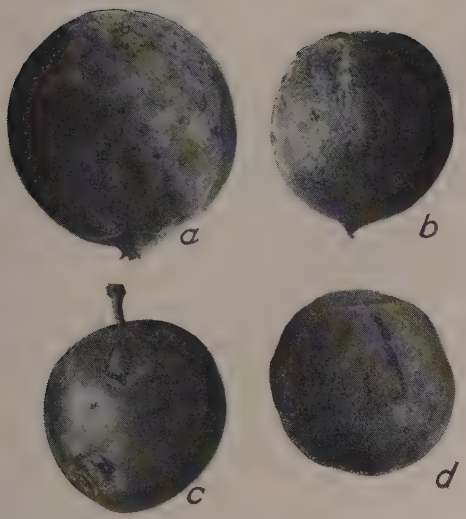

Fig. 63.— *Naturally infected fruits of peach, nectarine, plum, and apricot: a, Crothier peach; b, Victoria nectarine; c, Abundance plum; d, Bread apricot. (Photograph made on July 1, 1909)*

Fig. 64.—*Elberta peach fruit showing injury by Bacterium Pruni. The tree was sprayed seven times. The first application was made with lime-sulfur solution, 15-15-50 formula, on March 12, shortly before the fruit buds had opened. The other six applications were made with self-boiled lime-sulfur mixture, 12-8-50 formula. The first of these applications was made on April 21, just after the leaf buds opened; the others followed at intervals of about twelve days. Fifty-two per cent of the fruit was dotted with numerous cracks. (Photograph made on August 12, 1908)*

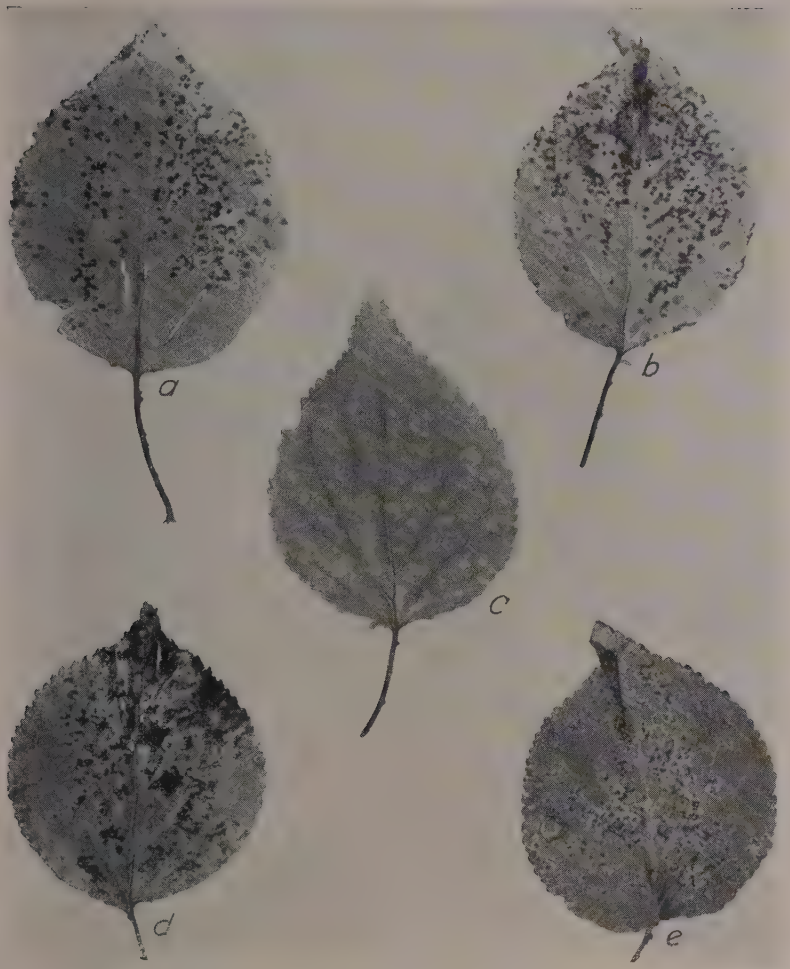

Fig. 65.—*Alexander apricot leaves inoculated with pure cultures of Bacterium Pruni. The growth from a six-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and then applied to the leaves by dipping the fingers into the water and gently rubbing the leaves between thumb and fingers. Inoculations were made on June 29, 1912, and the photograph was made on August 27, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Check. Sterile water was applied to the leaves
d, Inoculated with a pure culture obtained from a peach twig
e, Inoculated with a pure culture obtained from a plum twig

FIG. 66. — *Burbank plum leaves inoculated with pure cultures of Bacterium Pruni. The growth from a seven-days-old-slant Hiss-glucose culture was thoroughly mixed in one hundred cubic centimeters of sterile water and applied to the leaves by dipping the fingers into the water and then gently rubbing the leaves between thumb and fingers. Inoculations were made on June 27, 1912, and the photograph was made on August 27, 1912*

a, Inoculated with a pure culture obtained from an apricot twig
b, Inoculated with a pure culture obtained from a nectarine twig
c, Check. Sterile water was applied to the leaves
d, Inoculated with a pure culture obtained from a peach twig
e, Inoculated with a pure culture obtained from a plum twig

fall. The older, first infected leaves are usually, although not always, the first to go. One leaf after another falls, leaving finally only a tuft of young leaves at the tip of each twig and giving the tree a characteristic appearance (Fig. 60).

On the twigs

In some seasons black cankers form on the twigs in early spring, but as a rule these do not appear in abundance until May or June. The first visible indication of the canker is the appearance on the young shoots of a water-soaked spot surrounding a lenticel. In some cases the diseased area bulges out, more or less, in the beginning. As the spot enlarges it soon elongates. Single spots measure from one to four centimeters in length and often extend from one-half to two-thirds of the way around the shoot. The area becomes more or less sunken in age, soon becomes brown or purplish brown, then dark brown, and finally purplish black or black (Fig. 61). It frequently happens, especially on the nectarine and the peach, that several of the spots become confluent, forming areas which extend from two to three inches along the stem and in some cases completely girdle it. In favorable seasons the tips of many of the shoots are entirely blackened and killed (Fig. 62), this condition being most prominent on the nectarine and the peach. In most cases the injury is overcome gradually, and as a rule all traces of these black cankerous spots disappear in the second year.

The black spots on apricot twigs also disappear for the most part, but on plum twigs many of them persist from year to year, forming perennial cankers. As many as twenty-two cankers in different stages of development have been counted on a single plum twig (a water sprout). Open cankers also form on the apricot, the nectarine, and the peach, but they are far less abundant on these trees than on the plum.

The disease is usually more aggressive during the first two or three years after planting than it is later. It is not only likely to defoliate the young trees prematurely, but in many instances it kills back the twigs and frequently stunts the trees. A case of this sort was under observation, in which two hundred Elberta peach trees from an infected nursery were mixed with a shipment of twenty-three thousand healthy trees. Within three years from the time of planting, every tree in the orchard was more or less diseased, and many of the trees remained small and produced small, inferior fruit.

On the fruit

The disease does not ordinarily appear on the fruit until about the middle of May. Injured fruits of all the four kinds of hosts, however, have been collected early in May (Fig. 63). The first external signs of the disease are numerous small gray specks just below the cuticle. These specks enlarge slightly and soon take on a water-soaked appearance or a purplish color. The skin over the spots is soon ruptured, producing numerous straight or angular cracks which resemble the wounds on chapped hands (Fig. 64). Usually individual spots do not measure much more than two millimeters in diameter, but they are often so numerous that the cracks soon become confluent and frequently form a network, fissures nearly an inch in length being developed in some cases. On young growing fruit it is not uncommon to find rifts extending nearly the entire length of the fruit. Such wounds mar its appearance and in many cases render it worthless for market.

On all kinds of fruit the disease results in the formation of these small, more or less abundant, crack-like wounds, but certain varieties of the nectarine are especially liable to this type of injury. In some cases the spots gradually widen and extend for a considerable depth into the tissue, forming roundish, sunken, black spots which finally measure from one-fourth to one-half inch in diameter. Rifts develop in the blackened tissue. These widen, and cracks appear throughout the diseased area which often (especially when the disease is on young developing fruit) finally extend beyond the dead into the healthy tissue. In many cases the fruit becomes so badly distorted and cracked that it is worthless, and it is soon destroyed by various rot-producing organisms.

ETIOLOGY

Historical

The pathogen causing this disease was first isolated by the writer in 1904 at the University of Florida. Many poured plate cultures were made from the spots on injured leaves of both peach and plum. Cultures made from the young water-soaked spots invariably gave numerous yellow bacterial colonies, and in no case was a species of Cercospora or Cylindrosporium obtained. Consequently it was concluded that the disease was of bacterial origin. It was observed also that the defoliated

twigs sometimes showed one or more blackened, slightly sunken areas. These often measured as much as seven millimeters in width and extended from five to fifty millimeters along the stem, in some cases the entire end of the twig being blackened. Cultures from these areas produced yellow bacterial colonies.

On taking up work at the Missouri State Fruit Experiment Station in 1906, the writer observed that the twigs of some varieties of peach and plum in Missouri also showed blackened, sunken areas, and poured plate cultures from the diseased tissue in many cases gave yellow bacterial colonies. About the middle of June, 1906, it was observed that the foliage of trees bearing the diseased twigs had developed the shot-hole condition to a marked extent, while the foliage on trees with twigs free from the blackened areas was quite free from shot-hole. The fruit on Abundance and Burbank plum soon developed many typical black-spot areas, from which pure cultures of a yellow organism were easily obtained. A little later many peach fruits developed numerous small cracks. These were at first supposed to be due to the work of curculio, but a careful examination showed bacteria to be present in enormous numbers.

A careful study soon proved that the organism had invaded the apricot and the nectarine in much the same way as it had the peach and the plum. The fruit of the nectarine in the station variety orchard in 1906 was so badly cracked as a result of the attack of this organism that the entire crop was destroyed by various decay organisms long before the ripening period. Some of the apricot fruits developed the typical black spot. The twig cankers on both apricot and nectarine were fully as plentiful as on the peach, and premature defoliation also occurred on both apricot and nectarine trees.

Nomenclature

Since bacteriologists have not yet adopted an international code of nomenclature, it does not seem advisable to enter here into an extended discussion of the limits of genera, the selection of types, or the position of this organism in the various systems of classification proposed. The writer has therefore elected to follow arbitrarily the suggestion given by Erwin F. Smith (1905a). The organism was first described by Smith (1903) under the name *Pseudomonas Pruni*. Later, however, it became *Bacterium Pruni*, when Smith substituted the generic name Bacterium Cohn emend. for Pseudomonas Migula.

Pathogenicity

Conclusive proof of the pathogenic nature of this organism was obtained in 1904 by Smith (1905 a), by inoculating the foliage and the fruit of Abundance plum. The pure culture of the organism used in inoculation was obtained from plum fruit of the same variety. The organism from several young-slant agar cultures was scraped into two hundred cubic centimeters of sterile water and sprayed with an atomizer on the foliage and fruit of a five-years-old tree. Diseased spots developed on both leaves and fruit in from ten to twelve days and became numerous after fourteen days. Poured plates from the fruit and the leaves of the inoculated trees yielded numerous colonies of the yellow organism. In 1907 Smith (1908) also successfully inoculated the foliage of a peach tree with the plum organism. Rorer (1909) isolated the organism from peach leaves in 1906, and the following year made a series of successful inoculations with it on the foliage of Elberta peach trees at Bentonville, Arkansas. His results agree in every way with those obtained by Smith with the plum organism. Rorer also obtained pure cultures of the organism from peach twigs and reported its occurrence on peach fruit. He found the cultural characters of the plum and peach organisms to be exactly the same.

In 1907, at Mountain Grove, Missouri, the writer repeated and confirmed Smith's experiments on the plum, and extended the infection experiments to apricot, nectarine, and peach. The organism used was isolated from an Abundance plum fruit and grown in pure culture. The organism was scraped from several slant agar cultures into one hundred cubic centimeters of sterile water, and sprayed with an atomizer on the fruit and leaves of eight-years-old trees of Royal apricot, Victoria nectarine, Elberta peach, and Abundance plum. The inoculations were made during a light, drizzling rain. Disease spots developed on fruit and leaves of all four hosts within twelve days, and after fifteen days they became very numerous. Poured plates from the fruit and the leaves of the inoculated trees yielded numerous colonies of the yellow organism. However, several of the check leaves on the apricot and the nectarine trees also developed spots from which the yellow organism was obtained. Pure cultures of the organism were obtained by the writer from leaves and twigs of apricot, nectarine, peach, and plum. These strains and the one obtained from an Abundance plum fruit were grown side by side on various culture media, and were exactly alike in all cultural characters.

In 1909, at Mountain Grove, cross inoculations with the four strains obtained from the leaves were made on eight-years-old Royal apricot, Victoria nectarine, Elberta peach, and Abundance plum trees. Two hundred leaves, fifty fruits, and twenty twigs were used in each case. The organism from young-slant Hiss-glucose cultures was thoroughly mixed with sterile water and sprayed on the leaves and the fruit with an atomizer. Each of the twenty twigs was inoculated at four points with a hypodermic syringe. Spots appeared on the leaves of all the inoculated trees in ten days, and on the fruit in from twelve to fifteen days. The inoculated tissue on the twigs assumed a water-soaked appearance in from four to eight days, becoming dark brown and finally, in about twenty-five days, almost black. Poured plate cultures from the spots on leaves, fruit, and twigs yielded numerous colonies of the yellow organism. Three of the check leaves on peach also developed a number of brown spots.

In 1910, at Mountain Grove, cross inoculations with strains of the organism from the fruit of the four hosts were made on eight-years-old Royal apricot, Victoria nectarine, Elberta peach, and Burbank plum trees. Fifty leaves and ten twigs were used in each case. The organism from young-slant Hiss-glucose cultures was scraped into sterile water. The fingers were dipped into this water, and the material was applied to the lower surface of the leaf by gently rubbing the leaf between thumb and fingers. Each twig was inoculated at six points with a hypodermic syringe. Gray spots appeared on the leaves of all trees in from six to seven days, and water-soaked spots appeared in great numbers about the tenth day. The inoculated tissue on the twig assumed a water-soaked appearance in from five to seven days and became dark brown in about twenty-five days. Poured plates from the spots on leaves and twigs yielded colonies of the organism more or less abundantly. All the twig check wounds soon healed, and the check leaves remained free from spots.

In 1911, at Ithaca, New York, cross inoculations with the four strains obtained from the twigs of the four different hosts were made on three-years-old Elberta peach and four-years-old Abundance plum trees. The organism from young-slant Hiss-glucose cultures was thoroughly mixed with sterile water and sprayed on the leaves with an atomizer. Twelve twigs were used in each case, and each twig was inoculated at five points with a hypodermic syringe. Spots on the leaves developed in nine days,

and after twelve days water-soaked spots appeared abundantly. The inoculated tissue on the twigs assumed a water-soaked appearance in most cases by the seventh day. The typical black-spot and black-tip condition of the twig did not develop until after the twenty-fifth day. Poured plate cultures from the young leaf spots and the black spots on the twigs yielded colonies of the organism abundantly. Pure cultures of the organism from the twigs of the four kinds of trees were grown side by side on various culture media for six weeks, and in all cultural characters the strains were the same. All check wounds on the twigs soon healed, and the check leaves remained free from spots.

In 1912, at Ithaca, cross inoculations with strains of the organism from twigs of the four hosts were made on three-years-old Alexander apricot, Early Violet nectarine, Elberta peach, and Burbank plum trees (Figs. 59, 65, and 66). One hundred leaves and from twelve to twenty twigs were used in each case. The organism from young-slant Hiss-glucose cultures was scraped into sterile water. The fingers were then dipped into the water, and the material was applied to the lower surface of the leaf by gently rubbing the leaf between thumb and fingers. Each twig was inoculated at from three to five points with a hypodermic syringe (Fig. 61). Spots on the leaves appeared in from five to seven days, and water-soaked spots became numerous after the eighth day. The inoculated tissue on the twigs took on a water-soaked appearance in about seven days, but did not become dark brown until after the twenty-fifth day. Both leaf and twig spots yielded the characteristic yellow colonies on poured plate cultures. All check wounds on the twigs soon healed, and the check leaves remained free from spots.

Morphology

Vegetative cells.— The organism is a rather short rod, with rounded ends. It is found singly, in pairs, and, in liquid media, often in short chains. Individuals from a forty-eight-hours-slant Hiss-glucose culture are from 0.8 to 0.9 μ in length and from 0.3 to 0.5 μ in width. Bacteria taken directly from the twig cankers and stained with gentian violet measure from 1.6 to 1.8 μ in length and from 0.4 to 0.6 μ in width.

Endospores.— No endospores have been observed.

Flagella.— The organism is motile by means of one or several polar flagella. Both Pitfield's and Moore's flagella stains were used with

good results. The flagella were also stained without a mordant, by exposing the covers to carbol fuchsin for from twenty-five to fifty minutes and carefully washing in alcohol (Fig. 67).

Capsules.— Capsules have frequently been stained in material obtained from Uschinsky's solution by both Welch's and Moore's methods.

Zoogloœ.— Zoogloœ are frequently found on various media.

Involution forms.— No involution forms have been observed.

Staining reactions.—The organism stains readily with the ordinary aqueous stains — aniline gentian violet, and carbol fuchsin.

Gram's stain.— Many efforts at staining were made with Gram's method, but the results were not sufficiently sharp and decisive to warrant a conclusion. In no case was the stain completely lost, nor was it ever retained in the original intensity. The aniline gentian violet and iodine solutions were used for two minutes and the preparations were left in absolute alcohol for three minutes. In no case were the mounts washed in alcohol as intensely stained as those not treated with alcohol, and consequently the organism must be regarded as Gram negative.

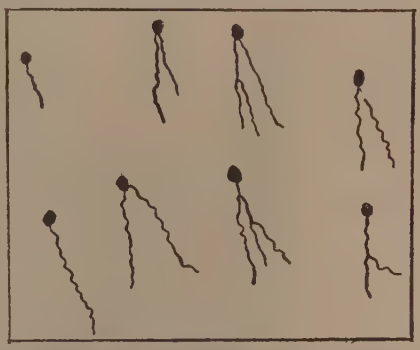

Fig. 67.—*Flagella of Bacterium Pruni. Stained from a culture of the peach strain of the organism grown in bouillon*

Acid-fast.— The organism is not acid-fast.

Cultural characters

Source of cultures.— Eighteen strains were used for each test, one from the apricot, one from the nectarine, nine from the peach, and seven from the plum. The reactions of all the strains on the various media were uniform, and no marked differences were observed except in one of the plum strains, which invariably grew most rapidly. The growth of this strain on potato plugs was more abundant than that of any of the other strains. Its growth on Hiss-glucose was often a number of hours in advance of the other cultures. Where there was any difference in the reaction one of the normal plum strains was always used as a basis for comparison.

Nutrient agar colonies.— When plantings were made from bouillon cultures six days old at room temperature of about 25° C., the colonies appeared as mere specks in from forty to forty-eight hours. Plantings made from diseased host tissue developed colonies in from three to ten days (usually from four to seven). No growth occurred at 37° C. The colonies were moist and glistening, and at first were almost white but later became amber yellow.[3] When not crowded, the surface colonies were round and reticulate, and reached a diameter of about one to five millimeters in ten days, with a smooth surface, an entire edge, and a finely granular internal structure. The deeper colonies were elliptical or lenticular. On plates twenty-five days old, colonies measured from ten to twenty-five millimeters in diameter. They had dark, translucent centers surrounded by a much lighter, often concentrically ringed, zone.

Nutrient agar streaks.— On slanted agar the streak made with a platinum needle developed a moderate amber-white (4) growth. The streak widened slowly, chiefly toward the bottom, made a filiform growth, and was raised, with a slightly contoured surface and an entire edge; it was translucent, with a glistening luster, and was slightly viscid; it did not color the agar on which it grew, at least not for a number of weeks. Growth was moderate. After five or six days the growth began to flow downward, and finally accumulated in an amber yellow (1), slimy mass at the base of the slant.

Nutrient agar stab.— On agar stab the growth was filiform, and was best toward the top of the stab, there being very little or no growth in the lower half of the medium. A circular colony formed on the surface at the point of inoculation, and gradually spread, completely covering the surface in about seven or eight days with a straw yellow (2) growth. The agar was not liquefied nor softened.

Gelatin colonies.— On gelatin plates at room temperature of about 25° C., the colonies appeared as mere specks in from forty-five to fifty hours. They were at first almost white, translucent, moist, and glistening. On the fourth day they measured about one millimeter in diameter. Both buried and surface colonies were round, finely granular, and with an entire edge, becoming with age amber yellow (2) in color. Liquefaction began usually on the third day, the colonies becoming saucer-shaped, spreading, and liquefying the medium in twelve days or more.

[3] All the color terms used in this paper are based on René Oberthür's *Répertoire de Couleurs*, published by La Société Française des Chrysanthémistes in 1905.

Gelatin streaks.— On slanted gelatin (+ 15) at room temperature of about 25° C., the streak having been made with a one-millimeter loop, a light, semi-transparent growth was noticed after two days along the entire path of the loop. In four days there was a slight liquefaction along the streak. On the fifth day the growth was amber yellow (1) in color, liquefaction had extended the entire length of the streak, and the growth was about ten millimeters wide and five deep. On the eighth day all material in the slant down to three millimeters below the base of the slant had been liquefied. Complete liquefaction occurred in from twelve to thirty days.

Gelatin stab. — In gelatin stab the path of the needle became beaded, but usually in the upper twenty-five millimeters of the medium it at first became more or less filiform. The growth on the surface was most rapid, and liquefaction, which began about the third day, soon passed to the walls of the tubes and then slowly downward. The growth in the depth of the gelatin soon ceased and the material along the track of the needle was not liquefied more rapidly than that away from its path. The liquefied gelatin was at first more or less clouded and was of about the same color as the solid material, but later it cleared and took on a raw sienna (2) color. A bacterial layer Naples yellow (3) in color soon formed on the solid gelatin and gradually settled as the material liquefied. Both a rim and a pellicle, cream yellow (2) in color, finally formed. Complete liquefaction occurred in from several days to six weeks or longer, depending on the temperature, the strain of the organism, and the composition of the culture material. In four months the liquefied material was viscid, was raw sienna (4) in color, and had a thick, slimy, Naples yellow (3), bacterial deposit in the bottom of the tube.

Hiss-glucose colonies.— Plantings made on Hiss-glucose from six-days-old bouillon cultures came up in from two to ten days (usually from four to seven) at room temperature of from 23° to 25° C., forming colonies from one to four millimeters in diameter in about eight days. No growth occurred at 37° C., but at 25° C. colonies appeared in forty-eight hours. The colonies were at first almost white, translucent, moist, and glistening, but later became amber yellow (1). When not crowded, the surface colonies were round, with an entire edge, the surface being smooth with a more or less convex elevation, and the internal structure being finely granular. The deeper colonies were elliptical or lenticular in form. Plates

containing twenty cubic centimeters of the medium developed single surface colonies in thirty days which measured from sixteen to thirty millimeters in diameter. The older colonies were amber yellow (4) in color, were convex, showed a dark central nucleus, and were often concentrically ringed. The smaller, thin colonies had a semi-transparent luster.

Hiss-glucose streaks.— On Hiss-glucose slant-tube medium (+15), the streak having been made with a millimeter loop, growth was noticed in forty-eight hours at room temperature of about 25° C. A convex, slimy, straw yellow (2) growth developed along the path of the loop. The streak widened gradually (chiefly toward the bottom), soon became filiform, and in ten days completely covered the slant with a slimy yellow (2) growth. In culture three or four months old the medium was browned. Some of the growth soon moved downward and formed a slimy deposit at the base of the slant, which finally became amber yellow (4) in color. As the medium dried out the slimy deposit gradually settled, and in the five- and six-months-old cultures there was a slimy, amber yellow (4) bacterial deposit from five to ten millimeters deep in the bottom of the tube. Inoculated tubes placed in the incubator at about 37° C. also covered the slants in ten days, but the growth was of about the same color as the medium.

Hiss-glucose stab.— In Hiss-glucose stab the growth was filiform and best toward the top of the stab, there being very little or no growth in the lower part of the tube. A circular growth formed on the surface at the point of inoculation, and covered the surface in six or seven days. The medium was not liquefied nor softened.

Potato agar streaks.— In potato agar a slightly raised, wet, shining growth developed along the path of the needle in two or three days at room temperature of 25° C. The streak gradually widened, and finally covered about two-thirds of the surface of the slant, becoming amber yellow (1) in color. Some of the slimy growth soon moved downward and formed a deposit at the base of the slant. Growth was moderate, never completely covering the slant.

Dextrose litmus agar streak.— In dextrose litmus agar, there was slight growth along the path of the needle in two days. The streak was slightly elevated, and widened most rapidly at the bottom, becoming filiform. The slimy growth passed downward and accumulated at the base of the

slant, and the medium below the mass became entirely bleached in five or six weeks.

Lactose litmus agar streak.— Growth in lactose litmus was not so marked as on the dextrose litmus medium. There was slight growth along the path of the needle by the close of the second day. The streak was slightly elevated, and it gradually widened and became filiform. The slimy growth passed downward and accumulated at the base of the slant. Growth was less abundant, and bleaching below the slimy mass only slight, at the end of six weeks.

Potato plugs.— Potato plugs were placed in running water for three hours, and were then put into tubes containing over five cubic centimeters of distilled water (the lower end of the plugs being in the water) and sterilized for twenty-five minutes at 100° C. for three consecutive days. The streak was made with a platinum needle from a six-days-old nutrient agar culture. The tubes were kept at room temperature of about 25° C. A slightly yellow, glistening streak developed along the path of the needle in two days. It made a moderate, slightly raised, echinulate growth, covering from one-half to two-thirds of the slant in about ten days but never completely covering it. One of the strains, however, repeatedly covered the entire surface of the cylinders in from five to six days. The growth had a contoured, wet, glistening, amber yellow (2) appearance. It was slimy, was free from odor, and turned the cylinder slightly gray. Most of the strains had only a slight action on potato starch.

Bouillon.— Both meat broth and meat extract bouillon were used. The meat broth material gave an acid reaction of + 15 Fuller's scale, and the meat extract bouillon recorded + 12. Inoculations were made from a three-days-old bouillon culture. All cultures were kept at about 25° C.

The medium was clouded after from twenty-four to forty-eight hours. An amber yellow (1) rim formed in from twelve to fifteen days, followed by formation of a pellicle. On being shaken, the material settled in the form of yellow, viscid flakes. The material cleared in about six or eight weeks and became raw sienna (3) in color, with a slimy, amber yellow (2) bacterial growth in the bottom of the tube. Very little difference was observed in the growths of the organism in extract bouillon and in broth bouillon.

Milk.— The milk used was maize yellow (1) in color, due to overheating in sterilizing, and was about 1.8 per cent acid. All tubes were

inoculated with a one-millimeter loop of beef broth culture three days old, and kept at 25° C. Two days after inoculation there was a slight whey ring at the surface of the milk; after four days the ring was three or four millimeters deep. Smith (1903) states that this organism slowly precipitates casein, which is then gradually redissolved.

In about ten days the whey ring was five or six millimeters deep and was amber yellow (3) in color, and the fluid curd gradually changed to yellowish tan (4) in color. The amount of clear whey gradually increased, and in about twenty-five days it became gamboge yellow (2) and the curd gradually became sienna (4) in color. The whey was viscid, while the mobile precipitate finally became a compact, slimy mass. An amber yellow pellicle was formed in from fifteen to twenty days. Filamentary threads often extended from the pellicle to the curd below. The pellicle finally settled. On shaking tubes containing a well-formed pellicle, yellow, slimy threads sometimes extended from the surface of the medium to the bottom of the tube.

An amber yellow (2) layer of the organism soon formed on the curd, and gradually lowered in the tube as the curd dissolved. About the twenty-second day many white tyrosine crystals formed in this layer.

About the forty-fifth day the pellicle in many cases had settled. The whey now constituted three-fourths of the material, was viscid, and was saffron yellow (4) in color. The precipitate was a yellow-buff (1), slimy mass dotted with white tyrosine crystals.

In four-months-old cultures the material was about one-half dried out and the whey constituted about one-half of the material. It was Indian chestnut-red (2) in color, with a thick, slimy, fawn-colored (2) coagulum dotted with white tyrosine crystals.

Litmus milk. — In the test with litmus milk, the culture material had been incubated at 37° C. for forty-eight hours just before the inoculations were made. It was violet (4) in color, and a one-millimeter loop of a three-days-old beef broth culture was used for inoculating each tube.

On the second day a bluish violet (4) ring two millimeters deep had formed on the surface of the medium, and by the fourth day the surface ring was from six to eight millimeters deep, in many cases having an amber yellow (1) rim. The material below the bluish violet (4) ring still retained its original color, but gradually became dark violet.

In about fifteen days the top ring became pansy violet (4) in color and was from eight to ten millimeters wide. The amber yellow (4) rim was more prominent and usually a pellicle was formed. In some cases the deposit below the whey had changed to madder brown (2) in color.

By the twenty-fifth day an amber yellow (1) pellicle had formed, in some cases with filamentary threads extending to the deposit below. On shaking of the tubes, the pellicle formed into thick, slimy threads sometimes extending from the surface of the medium to the bottom of the tube. In some cases the litmus was wholly reduced by the twenty-fifth day. The whey ring was about twenty-five millimeters deep, with the upper five millimeters pansy violet (3) and the lower twenty millimeters yellow lake (3) in color. The deposit in the bottom of the tube was brownish drab (2) in color, and was covered with an amber yellow (1) layer of the organism often three to four millimeters deep. Many white tyrosine crystals had formed in this layer. In about forty-five days the pellicle had settled, leaving a dull yellow-green (1) rim. The litmus had been in some cases completely, and in others only partially, reduced, but the material in most of the tubes had returned to a darker color. The whey by transmitted light was plum-violet (4) in color. There was a thick, slimy, brown-drab (2) deposit in the bottom of the tube, about 10 millimeters deep, and on the top of this an amber yellow (2) layer of the organism. Tyrosine crystals were scattered throughout the entire slimy mass.

In four-months-old cultures one-half of the material had dried out. The pellicle had settled, and a plum-violet (3) whey ring about twenty millimeters deep covered a thick, slimy, brownish drab (2) deposit six millimeters deep in the bottom of the tube. An amber yellow (2) layer of the organism on the top of the deposit was still rather prominent. Masses of white tyrosine crystals appeared throughout the entire slimy deposit.

Fermentation tubes.— A basal solution was made by adding two per cent of Witte's peptone to water. Six solutions were made from this, each containing one per cent, respectively, of one of the following carbon compounds: glycerin, saccharose, mannite, dextrose, maltose, lactose. Five fermentation tubes were filled with each of these solutions and sterilized by heating for twenty-five minutes on three successive days. Three tubes of each set were inoculated and two were left as a control. The inoculated tubes each received a one-millimeter loop of culture material from a five-days-old peach bouillon culture.

Five days after inoculation a cloudiness appeared in the open arm of each of the inoculated tubes. This turbidity increased with age, extending more than halfway into the U in the dextrose, saccharose, and maltose cultures; but at the end of twenty-five days there was no growth in the closed arm and no gas. There was a well-defined line between the growth in the bulb and the clear liquid in the closed arm, which seemed to point strongly toward the aërobic nature of the organism. A pellicle had formed on all the dextrose, maltose, and saccharose cultures, and in most cases there was a yellow, slimy growth of the organism at the bottom of the open arm. There was very little growth in the mannite tubes.

The cultures were tested for acidity after they had grown for twenty-five days. In glycerin the acidity increased from + 0.8 to + 1; in saccharose, from + 0.9 to + 1.1; in mannite, from + 0.9 to + 1; in dextrose, from + 1 to + 2.5; in maltose, from + 0.8 to + 1; in lactose, from + 0.8 to + 1.1.

Uschinsky's solution.— In the test with Uschinsky's solution, tubes were inoculated from a four-days-old broth culture. A one-millimeter loop of the material was placed in each tube.

The tubes were all clouded after three days. The solution often became viscid in about twenty-five days. A cream yellow (1) pellicle formed in from twenty to thirty days or later. The pellicle finally settled, forming a slimy, cream yellow (3) bacterial mass in the bottom of the tube.

Sodium chloride bouillon.— A one-millimeter loop of a six-days-old, + 12, peptonized beef broth culture was placed in tubes of peptonized beef broth containing, respectively, 1, 2, 3, 4, 5, 6, and 7 per cent of chemically pure sodium chloride. Three tubes were inoculated with cultures of each kind of host — apricot, nectarine, peach, and plum. At the end of seven days clouding was apparent in all tubes containing 1, 2, and 3 per cent of sodium chloride. Both the peach and the plum organisms grew in a 3.5-per-cent salt bouillon. There was no clouding in the 4-, 5-, 6-, or 7-per-cent solutions.

Growth in bouillon over chloroform.— By means of a sterile pipette, five cubic centimeters of chloroform was added to fifteen cubic centimeters of bouillon. Fifteen tubes were shaken twice a day during the period of this test. On the eighth day the tubes were divided into five lots, four of which were inoculated with six-days-old bouillon cultures of apricot, nectarine, peach, and plum organisms, respectively; the fifth lot being used as a

control. These cultures were under observation for thirty-two days, but no growth was observed in any of the tubes.

Nitrogen nutrition.— In filtered river water containing one per cent of asparagin, the organism made a slow initial growth first visible in six days. When distilled water was used the first signs of growth failed to appear before the tenth day, and in some cases as late as the fifteenth day, even when the strongest, oldest cultures were used. A very slight growth was obtained in river water containing only dextrose. River water alone failed to give any growth.

Nitrates.— Twelve tubes, each containing ten cubic centimeters of peptonized beef broth to which had been added one per cent of nitrate of potash, were divided into four lots of three tubes each. The solutions in each lot were then inoculated with apricot, nectarine, peach, and plum strains, respectively.

At the end of ten days the tubes were clouded and a tube from each lot was tested for nitrates in the following manner: To each culture one cubic centimeter of boiled starch water and one cubic centimeter of potassium iodide solution (1 200) were added. A few drops of sulfuric acid were then introduced. The peach and plum cultures gave a slight blue reaction, and on the twentieth day the remaining tubes each gave a distinct reaction. However, six months later these experiments were again repeated three times, with the same strains of the four organisms, and not a single culture gave the reaction.

Indol.— A number of tubes of Uschinsky's solution with the addition of one per cent of Witte's peptone were inoculated with a five-days-old agar culture. Apricot, nectarine, peach, and plum strains were used in making these inoculations. The inoculated tubes all showed considerable growth on the fifth day, but a test for indol was not made until the tenth day. Sulfuric acid water (1–2) and dilute sodium nitrate (1–200 in water) were used. On the tenth day all cultures gave a slight rose color after being placed in boiling water for two minutes, indicating indol production. The other tubes were tested twenty days later and a well-marked indol reaction was obtained from all the cultures.

Cultures of the four strains made in Dunham's peptone solution gave positive results at the end of twenty days. There was a trace of pink before heating, and after four or five minutes in a water bath at 80° C. the reaction became distinct.

Toleration of sodium hydroxide.— Beef bouillon having a reaction of +10 Fuller's scale was used. Sufficient sodium hydroxide was added to obtain a reaction of 0, —2, —4, and so on for every two degrees of Fuller's scale to —30. The sodium hydroxide was added just before the last sterilization. Titrations made immediately following the sterilization, while the medium was still warm, showed an apparent loss of alkalinity. In many cases, although not always, the check lots of the medium titrated on the fifth day or later gave the original reaction.

Tubes inoculated and placed in an incubator at 25° C. gave a good growth in all cultures down to —10 in forty-eight hours. There was a slight growth in the —10 cultures, and at the end of two weeks a very slight growth occurred in the —13 cultures. No growth occurred in the tubes containing larger amounts of sodium. The best growth was in cultures containing from —2 to —4 sodium hydroxide.

Toleration of hydrochloric acid.— Ordinary beef bouillon having a reaction of + 12 Fuller's scale was used. Sufficient hydrochloric acid was added to 100 cubic centimeters of the bouillon to obtain a reaction of + 14, + 16, and so on for every two degrees of Fuller's scale to + 36. There was a very good growth in forty-eight hours in all the tubes up to + 22, and a slight growth in the lot having a reaction of + 24. A very slight growth was observed on the fourth day in the medium having a reaction of + 26; this growth became slightly stronger by the tenth day. No growth occurred in any medium containing larger quantities of acid. The best growth developed in lots containing from + 12 to + 20 acid.

Resistance to drying.— Small drops of four-days-old bouillon culture were placed on sterile cover glasses in a covered sterile petri dish, and left in an incubator at room temperature of from 18° to 23° C. At intervals of twenty-four hours one of the cover glasses was transferred to a tube of sterile bouillon. Three tubes were used for each test. Growth occurred up to the eighth day, after which the tubes remained sterile.

This experiment was repeated a number of times with bouillon cultures from four to ten days old. As a rule there was no growth after the eighth day; in one case, however, growth occurred on the fifteenth, and in another case on the twenty-first, day.

Effect of sunlight.— Hiss-glucose tubes inoculated from a three-days-old bouillon culture were poured into petri dishes and placed in the bright sunlight for forty-five and sixty minutes, respectively, half of each plate

being covered with black paper. After six days, on each of six plates there were numerous colonies on the covered parts but none on the exposed parts. A few colonies, however, developed on the uncovered parts of all the plates exposed for fifteen, twenty, and thirty minutes.

Effect of germicides.— Poured Hiss-glucose plates were made with the plum organism after it had been exposed to various concentrations of copper sulfate, mercuric chloride, formaldehyde, lime-sulfur solution, the self-boiled lime-sulfur mixtures, and arsenate of lead.

In a copper sulfate solution (1–10,000), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were only one-fourth as many colonies on the five-minutes exposures as on the one-half-minute exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a mercuric chloride solution (1–150,000), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. The colonies on the plates exposed for five minutes remained small and failed to develop the yellow color. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a formaldehyde solution (1–300), colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were three times as many colonies in the one-half-minute exposures as in the five-minutes exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a lime-sulfur solution (15–15–50 formula) in a 1–10,000 dilution, colonies appeared in five days on all plates on which cultures were made of the organism which had been exposed for one-half minute and for five minutes. However, there were only one-half as many colonies on the five-minutes exposures as on the one-half-minute exposures. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In a self-boiled lime-sulfur mixture (8–8–50 formula) in a 1–52 dilution, colonies appeared in five days on all plates on which cultures were made

of the organism which had been exposed for one-half minute and for five minutes. No colonies appeared on any of the plates on which the organism had been exposed for fifteen minutes and for thirty minutes.

In arsenate of lead, 1–208 dilution, colonies appeared on all plates on which the organism had been exposed for one-half, five, fifteen, and thirty minutes, respectively.

Diastatic action.— The test for diastatic action was made on potato cylinders. Twenty-eight strains of the organism were grown on potato cylinders for twenty-five days. The cultures were then tested for starch reduction, and only one of the strains showed marked diastatic action. In all the other cases the only indications observed were a slow and slight tendency toward the conversion of starch into amylodextrin, shown by a gradual change in the iodine reaction from a clear blue to a purplish tint.

These tests were made according to the directions given by Harding and Morse (1909): "These potato cultures were crushed in porcelain mortars and 50 cubic centimeters of water added to separate the particles so that the effect of the iodine could be easily seen. The presence of unchanged starch was determined by the gradual addition of a weak solution of iodine in potassium iodide. After a sufficient amount has been added to satisfy some of the other compounds which are present the starch grains are turned to a blue-black. The extent of the reduction of the starch by the bacterial growth is estimated on the basis of similar tests of uninoculated potato cylinders."

The uninoculated cylinders, when tested with the iodine-potassium-iodide solution diluted with water, always yielded a bright blue reaction. The starch reaction was also strong after the organism had been grown on the cylinders for several weeks, although a purplish color indicated a slight diastatic action.

Fragments of potato scraped from under the yellow slime from a culture forty days old, mixed with about twenty times their bulk of water, gave a purple or a blue-purple reaction. When fragments of material from the back or the center of the cylinder were used and treated in the same way, they invariably gave the blue reaction. The water below the potato cylinder, when it contained more or less of the yellow slime of the organism, also invariably gave a purplish blue reaction.

Pepsin.— A peptonizing ferment must be present, since gelatin is liquefied and casein is slowly dissolved with the formation of tyrosine.

Lab ferment.— In the milk cultures the casein is thrown out of solution without marked acid production, which indicates the presence of a lab, or rennet, ferment.

Invertase.— Cultures of all four strains of the organism were grown in filtered river water containing two per cent of chemically pure saccharose and two per cent of Witte's peptone. On the twenty-fifth day all the cultures were tested for inverted sugar with Fehling's solution, and every culture gave the glucose reaction.

Thermal death point.— Preliminary tests indicated that the thermal death point must lie between 49° and 54° C. The following tests were made to determine the point more nearly: Six sets of twelve tubes each of peptonized beef broth were inoculated with the peach organism from a five-days-old-slant Hiss-glucose culture, and the tubes were placed in water at a constant temperature of 49°, 50°, 51°, 52°, 53°, and 54° C., respectively. The tubes were removed at the end of ten minutes, and were kept at 25° C. for two weeks. At the end of five days growth had taken place in all the tubes that had been exposed at 49° and 50° C. Growth appeared also in three of the twelve tubes that had been kept at 51° C. No growth appeared at the end of fourteen days in tubes that had been kept for ten minutes at 52°, 53°, and 54° C.

The experiment at 51° and 52° C. was repeated several times with different strains of the organism, and in a few instances growth occurred in cultures kept at 51° C. for ten minutes. There was never any growth in cultures kept at 52° C.

The thermal death point, therefore, is about 51° C. Smith (1903) also placed the thermal death point of this organism at about 51° C.

Optimum temperature.— The optimum temperature appears to lie between 24° and 28° C. Growth at 24° and at 28° C. on Hiss-glucose and peptonized beef bouillon was considerably better than at 32° C. Growth at 20° and at 36° C. was about the same, but was considerably less than at 32° C. and much less than at 24° or 28° C.

Maximum temperature.— Four-days-old bouillon cultures of ten strains of the organism were used to inoculate slant Hiss-glucose medium. Six tubes were used for each strain; three tubes of each lot were placed in an incubator at 37° C., and three were kept at room temperature. All cultures, both in the incubator and at room temperature, made good growth; however, those exposed to the higher temperature were of the

color of the medium, while those in the lower temperature had developed the normal yellow color. On the fifteenth day the heat of the incubator was reduced to 25° C.; on the sixteenth day one of the cultures had taken on a yellow color, and by the eighteenth day all the cultures had developed the normal color. From these results it is evident that 37° C. is close to the limit of growth for the organism on Hiss-glucose.

In a series of experiments, slant Hiss-glucose and bouillon cultures were kept at 20°, 24°, 28°, 32°, 36°, and 40° C., respectively, for three weeks. Six-days-old bouillon cultures of four strains of the organism were used for making the inoculations. Two three-millimeter loops of the fluid were used for each tube. Three tubes of bouillon and two of the slant Hiss-glucose medium were used in each set. Five tubes of bouillon and three of the Hiss-glucose medium were also inoculated and were placed at room temperature (from 23° to 25° C.), to serve as checks. All strains of the organism on both kinds of media made decidedly the best growth at 24° and at 28° C. They also made better growth in both media at 20° than at 32° C., and the growth at 32° was considerably better than at 36° C. There was no growth at 40° C.

The growth on Hiss-glucose cultures kept at 20° and at 24° C. developed the normal yellow color; tubes kept at 28° C. developed a growth a shade lighter in color; those kept at 32° C. were much lighter, and had a mere trace of yellow; in those kept at 36° C. the yellow shade had disappeared entirely, and the growth was of the color of the medium.

Loss of virulence.— Park (1905) states that "bacteria differ . . . as to the ease and rapidity with which they grow in any nutritive substance and the amount of poison they produce. Both of these properties not only vary greatly in different members of the same species, but each variety of bacteria may to a large extent be increased or diminished in virulence."

In June, 1910, four cultures, one each from apricot, nectarine, peach, and plum twigs, were obtained at Mountain Grove, Missouri. All the cultures were grown continuously on a Hiss-glucose medium. It was observed that the plum organism obtained at this time was the most vigorously growing strain in the laboratory. In the inoculation work in Missouri during 1910 it was also the most aggressive on all four hosts. In the work at Cornell University during 1911 the writer was much surprised to find that not only had this strain lost its vigor on the various

culture media, but the injury was also far less marked when it was inoculated on the green tissues of the different hosts. In the fall of 1911 Abundance plum twigs were inoculated with cultures of this strain, and in the summer of 1912 the organism was regained from one of the twigs. The culture was again grown continuously on a Hiss-glucose medium. The regained culture made a slightly better growth on the various media than did the culture which had been growing continuously on the Hiss-glucose medium, and was also slightly more aggressive when inoculated on the green tissues; but it was far less virulent than when first obtained. In the summer of 1912 the four old strains which had been growing continuously on the Hiss-glucose medium since 1910 were rejuvenated by growing them in bouillon for fifteen days, making transfers to a new medium every third day, and finally on the fifteenth day all were again placed on the Hiss-glucose medium. The plum organism at once became again the most vigorous grower, and when inoculated on peach leaves and twigs it was also the most aggressive. From these results it appears that vigor is the controlling factor in the virulence of the organism.

Group number.— The group number, according to the descriptive chart of the Society of American Bacteriologists, is 211.2232523.

Life history

Inoculation.— *Bacterium Pruni*, so far as is known, passes its entire life cycle in nature within the tissue of the host. The disease usually makes its appearance in the spring shortly after the leaves have unfolded, but as a rule serious outbreaks do not occur before May and often not until later. Cankers on the twigs and limbs are the principal sources of infection in the spring. Trees bearing twigs on which inoculations result in the development of well-formed cankers, are invariably the first to develop leaf spot abundantly the following year. Young trees which suffer severely from repeated outbreaks of the shot-hole condition usually show many twig cankers. Twig cankers are also constantly associated with the early spring outbreaks on older trees. The tissues of the bud may likewise become invaded, and are often responsible for the early spring infection. Eleven out of fifty cultures made from the centers of buds taken in August from peach twigs on which the foliage was badly shot-holed, yielded many colonies of the yellow organism.

The bud cut from bud wood obtained from an infected tree often conveys the organism to healthy stock. Laboratory experiments indicate that when exposed to sun and air the bacteria which lodge on twigs and buds retain their vitality for only a very short time.

If the twigs are killed after the cankers are well formed, the organism may remain alive in the dead tissue for a considerable time. Many peach and plum twigs cross-inoculated by the writer in the summer of 1910 died in the following winter, but cultures of the organism were repeatedly obtained from the dead twigs up to the middle of the next June. From that time on it was impossible to secure cultures from this source. Cultures were readily obtained, however, from the cankers on the green inoculated twigs.

Old leaves on the ground, if well protected from sun and air, may possibly harbor the organism for some time, but it is doubtful whether they ever constitute an important source of infection. It is possible that pruned twigs and limbs left on the ground may occasionally be the source of primary infection, but in the large percentage of cases the primary infection can be traced to cankers on twigs and limbs of the trees. The writer's experiments indicate that the organism soon loses its vitality in material on the ground.

Fig. 68.—*Cross section of a peach leaf which was inoculated with a strain of Bacterium Pruni from the fruit of the plum. The material was collected eight days after the inoculation had been made. The organism entered the leaf through the stomata. (Drawing made with the aid of a camera lucida)*

In October, 1911, fifteen hundred peach leaves, one thousand plum leaves, and fifty peach twigs, which had been cross-inoculated with cultures of the four strains of the organisms, were put between wire screens and left over winter on the ground, where they were fully exposed to the sun. In April, 1912, all attempts to regain the organism from these twigs and leaves failed. In another experiment, however, Hiss-glucose poured-plate cultures made on June .1, 1913, from diseased leaves that had been collected on October 10, 1912, and kept in the laboratory between blotters, yielded colonies of the organism.

The organism gains entrance to the host through the stomata (Figs. 68 and 69) and the young lenticels during periods of sufficient moisture. A film of water on the surface of the leaf, the twig, or the fruit enables the bacteria to move about and gain entrance to the substomatal cavity. Inoculation ordinarily does not take place in the absence of moisture. Lenticels and stomata are fairly well distributed on the young twigs, and the stomata are more or less plentiful on the green fruit and on the lower surface of the leaves, but there are none on the upper leaf surface. Consequently inoculation may occur anywhere on the young, tender twigs and the green fruit, while on the leaves the organism can gain entrance only from the lower side.

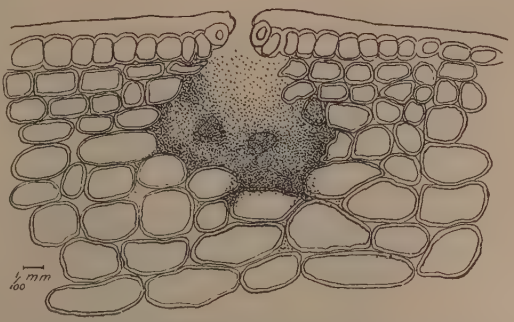

Fig. 69.—*Early stage of fruit spot on Burbank plum fruit. The fruit had been inoculated with a strain of Bacterium Pruni, isolated from a peach tree. The material was collected seven days after the inoculation was made. It was fixed in strong alcohol, infiltrated with paraffin, and cut on the microtome. The sections were stained with acid fuchsin. (Drawing outlined with the aid of a camera lucida)*

In 1911, at Ithaca, New York, 332 Elberta peach leaves of different ages were inoculated in the early morning. A few drops of water containing numerous bacteria in suspension were placed, by means of a pipette dropper, on the upper or the lower surface of each leaf. In all, 149 of the leaves were inoculated on the upper, and 183 on the lower, surface. In four weeks 177 of the leaves inoculated on the lower surface contained many spots; 6 were clean. All the 149 leaves inoculated on the upper surface were free from infection. In the same year 100 plum leaves were inoculated in the same way, 40 on the upper and 60 on the lower surface. At the end of five weeks, 55 of the leaves inoculated on the lower surface contained many brown spots, and 5 were free from lesions. All the leaves inoculated on the upper surface were free from spots. All the check leaves were normal.

From the results it was evident that a moist lower surface is essential for inoculation and spread of the pathogen on the leaves. Observations show that dew plays quite as important a part in the dissemination of the pathogen as does rain. Rain and dew are not only important factors for inoculation, but they also carry the bacteria to the healthy leaves, twigs, and fruit, and thus frequently serve as agents of transportation.

The bacteria are no doubt carried from tree to tree and disseminated on the young leaves, fruit, and growing twigs by insects of various kinds. Waite (1898), Stewart (1913), and others have proved that bees, wasps, flies, snails, aphids, and beetles carry the pear blight organism from oozing cankers to open blossoms and young shoots, and thus spread the blossom and twig blight of apples and pears throughout the orchard. From the large numbers of various insects often found working on the diseased foliage and fruit of trees affected with *Bacterium Pruni*, and from the nature of the bacterial ooze, there appears little doubt as to the importance of insects in the dissemination of this organism.

In spring, when the weather is cold and unfavorable for the development of the organism and the insects are sluggish, only a few primary inoculations occur and only a few scattered spots develop on the foliage. As the season advances and the weather becomes warmer, the bacteria multiply and escape from the spots of the early infections, the secondary infections gradually become abundant, and the leaves that contained only a few spots at first soon become dotted with them. Insects also become more active, and secondary spots of infection multiply rapidly.

In the inoculation experiments on plum leaves in 1913, snails and aphids were undoubtedly the chief agents in conveying the organism from the inoculated diseased leaves to the young leaves as they unfolded. The new leaves of the trees on which there were no snails nor aphids remained free from infection. Poured plate cultures were made from each of eleven snails and eighteen aphids collected from these trees. Three of the snail cultures and two of the aphid cultures yielded colonies of the organism.

The great frequency with which infection occurs on the leaves along the path taken by ants leaves little doubt that these insects also aid more or less in spreading the disease. Nevertheless, cultures from more than one hundred ants gave negative results.

As a rule, insects merely carry the virus from leaf to leaf or from tree to tree, and seldom introduce the bacteria directly into the tissue of the host.

Still the writer has frequently obtained cultures of the organism from both feeding and egg punctures of curculio on fruit, and in a number of cases it has been practically certain that the insect was the agent of inoculation.

Infected leaves are often blown about by the wind, and no doubt are sometimes responsible for the occurrence of primary infection. Yet danger from this source is comparatively slight, since the leaves soon dry out and the bacteria quickly lose their vitality. The disease usually advances in the orchard in all directions from a center of infection, often forming a more or less circular diseased area. After the organism has become established, the movement of limbs and branches caused by high wind during storms also furnishes a means of conveyance for the bacteria from diseased to healthy organs.

Old neglected trees, the plum in particular, often serve as sources of inoculum. In the past seven years two outbreaks of the disease on the Missouri State Fruit Experiment Station grounds were traced directly to infected Burbank, Abundance, and Golden plum trees.

Where the organism has become well established, diseased trees may serve as a source of inoculum and young trees planted in adjoining fields gradually become diseased. In 1906 a very striking case of this sort came under observation. A tract of one hundred and sixty acres of land on the east side of an old peach orchard at Koshkonong, Missouri, which contained many infected trees, was planted in the spring with two-years-old Elberta peach trees. In October the foliage and twigs of the trees in the ten rows next to the old trees were badly diseased. During 1907 the organism gradually advanced, and by the close of the season the trees in one hundred and ten rows were infected. The disease, however, was much worse in the first thirty rows than in the others. During 1908 the organism spread entirely across the orchard and every tree in the entire tract was injured to a greater or less extent. The trees in the first thirty rows next to the old orchard suffered most severely, and many of them were permanently injured.

Man himself is often an important agent of inoculation. In selecting material for budding, nurserymen frequently cut twigs from diseased trees, and thus, by inserting the infected bud material, inoculate the stock.

In 1907, on the Missouri State Fruit Experiment Station grounds, several thousand healthy peach seedlings were budded with buds taken

from infected Elberta twigs. During 1908 the shot-hole condition developed on the foliage of nearly all these trees, and cankers were more or less plentiful on the twigs of many of them. Trees of this sort, when set out, not only grow poorly, but also serve as centers from which all neighboring trees become inoculated. In the course of the past five years several cases have come under observation in which a few infected trees from a poorly kept nursery were mixed in large shipments of clean trees. The infected trees served after planting as inoculum centers, and three years after planting every tree in these orchards was diseased.

In a careful inspection of peach and plum trees in various sections of South Carolina, not a single case of the disease was observed on isolated seedling peach and plum trees; yet the organism was repeatedly collected on the budded peach and Japanese varieties of plum in both family and commercial orchards, indicating that the nurseries are largely responsible for the spread of the pathogen.

Incubation.—The period of incubation varies more or less, depending on temperature, moisture, and method of inoculation. The period is about the same on all four kinds of trees. In some cases, however, it appears to be slightly longer on leaves and twigs of apricot and plum than on those of the nectarine and the peach.

In experiments in which the organism was suspended in water and applied to the leaves and fruit with an atomizer in warm, moist weather, the period apparently varied from seven to fifteen days, but in cold weather the period was prolonged to twenty and even twenty-five days. When water containing the organism was applied in warm weather to the lower surface of the leaf and to the fruit by means of a pipette dropper, and was spread by gently rubbing leaf or fruit between the thumb and the fingers, signs of disease appeared on the leaves in from five to seven days and on the fruit after seven or eight days; in cold weather, however, the period was considerably extended on both leaves and fruit. On the twigs, considerable difficulty having been experienced in obtaining results with the spray and rubbing method, a hypodermic syringe was used. The needle was inserted just beneath the cuticle and a small quantity of water containing the bacteria was forced into the tissue. Very uniform results were obtained in this way. The period of incubation following these inoculations varied from four to ten days, depending largely on the temperature and on the number of organisms forced into the tissue. In the

twig experiments moisture did not influence the period of incubation to so marked an extent as in the experiments with leaves and fruit.

Infection.—Infection occurs soon after the bacteria pass through the stomata into the substomatal chambers, where they multiply and secrete a cytolytic enzyme which soon breaks down the cell walls of the neighboring cells, giving the organism access to an abundant food supply.

Serial sections made from infected plum fruit show that the organism at first occupies merely the substomatal chamber, but the neighboring cells are soon broken down, and as the bacteria multiply, the deeper tissues become involved. In about six or seven days a small cavity filled with bacteria is formed, and the first evidence of disease appears in the form of a water-soaked spot just beneath the stomata. A cross section through one of these spots shows the cavity filled with a compact mass of bacteria (Fig. 69, page 415). In about ten days or more, depending much on the weather conditions, the bacteria escape to the surface through the stomata or a slight central rupture. In some cases the bacteria burrow deeper and spread laterally, forming a somewhat circular, sunken, black area. The bacteria reach the surface through the various stoma and central rifts.

The tissues of the leaf are invaded in much the same way as are those of the fruit. At first the parenchyma tissues are those principally involved, but finally the vascular bundles also may be attacked (Fig. 68, page 414). The external signs of injury sometimes appear a day or two earlier on the leaves than on the fruit, and the ooze may also be evident a little earlier. The area in which the cells have been broken down assumes a more or less circular form and soon becomes separated by a line of cleavage from the healthy tissue. The injured tissue within this area soon contracts, dries out, and falls away, leaving a fairly clean-cut hole in the green tissue.

The tender tissues of the young shoots are also injured in much the same way, but the incubation period in the older tissues of the twigs is apparently longer and the development of the water-soaked spots is often slower. A cross section through one of these spots also shows a cavity filled with a compact mass of bacteria. The black-spot condition on the twig appears in from twenty to thirty-five days. Many of the phloëm cells of the sunken black area are broken down and the entire tissue is more or less

disorganized (Fig. 70). Radial rifts or pockets in the young wood and cortex extend outward, often to the epidermis. As the twigs increase in

Fig. 70. — *Cross section of a young peach twig inoculated with a pure culture of Bacterium Pruni obtained from a plum twig. Bacterial pockets are most abundant in the cortical parenchyma. All cortical parenchyma cells in the infected region are distorted. The bacterial pockets in the cambium region also are to be noted. Occasionally the large ducts in the young wood are filled with the organism*

size these rifts open and form an approximately longitudinal fissure. The bacteria escape through these fissures in countless numbers as bacterial ooze.

New infections occur only on the current season's growth. The organism is most aggressive in the young, tender tissues of the twigs. As the tissues harden, the influence of the organism in many cases becomes less marked and the blackened areas gradually become lighter in color; by the close of the season these areas have in many cases assumed much the same color as the old bark. During the second year a large proportion of the twig cankers thus disappear. A cross section of a twig through such cankers shows that no new bacterial pockets have appeared near the cambium zone and the old cavities have gradually been crowded into the outer bark. The organism, however, in some cases at least, is still alive and active, and no doubt often serves as a source of inoculum.

EFFECT OF ENVIRONMENTAL FACTORS

The condition of the weather is the most important environmental factor with respect to this disease. This is particularly true as regards moisture, but temperature is also of marked consequence. The shot-hole condition does not usually appear until about the middle of May or the first of June. In a very warm, damp spring, however, it may appear as early as the first of April, while in other years severe outbreaks may not appear until in August or even later. A temperature of from 20° to 28° C. is the best for the growth of the bacterium. Cold weather not only retards its growth, but also checks the activities of insects, which are the important agents in disseminating the organism. In the writer's spring and fall field work, it was frequently observed that when a cold period followed immediately after a series of inoculations had been made, the growth of the organism was retarded, and in some cases three, and even four, weeks passed before signs of disease appeared. The warm, slow, continued rains of the summer furnish the best conditions for the rapid spread of the disease. Heavy, driving rains of short duration followed by sunshine and winds are not favorable to its spread, since many of the bacteria are washed to the ground, and the leaves are quickly dried off and the few bacteria that may be spread will be quickly dried and killed.

The foliage of eight three-years-old peach trees, which were growing in boxes in the open, was inoculated with pure cultures of the organism. In three months the foliage on all the trees was dotted with brown spots. Four of the trees were then moved into the greenhouse and water was applied only to the roots. No new spots appeared on the old leaves

after the second week, and all the new leaves that developed in the greenhouse remained free from infection, while the leaves of the four trees in the open continued to develop many new spots.

The relation of moisture to the spread of the disease is also brought out to a marked extent in the field when a favorable wet period is followed by a dry period. All the leaves formed in wet weather contain many brown spots and usually develop the shot-hole condition more or less, while those formed in a dry period remain free from spots, the contrasts in the foliage of the two periods being sometimes very striking.

Heavy dews, if the temperature does not fall too low, also furnish favorable conditions for inoculations, and observations indicate that they often play quite as important a part in the progress of the disease as does rain.

Shaded situations are favorable for the growth of the organism. Direct sunlight soon kills it. However, since the stomata of the leaves occur only on the lower surface, and the twigs and the fruit are usually fairly well shaded by the leaves, only comparatively few of the organisms ever become exposed to the direct rays of the sun.

In dry seasons injury from this organism is very slight, especially if the spring has been cold. Infections in such seasons are found only in the center of the tree, where the foliage remains moist from the dew until late in the day.

While it is true that temperature and moisture are the factors that govern the distribution of the organism, yet soil conditions, fertilizers, and cultivation have a marked influence on the extent of injury done. The soil in which the trees are growing has a considerable influence on the development of the disease. When a general outbreak occurs in an orchard, the trees on the higher, thin ridges invariably suffer more than those on the lower, more fertile land. Trees that have borne the heaviest crops in previous years invariably suffer more than do those that have yielded little or no fruit in previous seasons. Young trees planted in new land properly broken up before planting are more nearly free from the disease than trees planted on land poorly prepared. Trees properly pruned and well cultivated show less disease than do those that are not pruned nor cultivated.

VARIETAL SUSCEPTIBILITY

Observations show that the different varieties of the various hosts exhibit considerable variation in their susceptibility to the disease. The

plums show the greatest variation. The majority of the American varieties suffer little, if at all, while nearly all the Japanese varieties, especially Abundance and Burbank, are severely injured, in some cases the disease resulting in the formation of deep limb and trunk cankers and in eventual death of the tree. Similar wounds are occasionally formed also on some varieties of apricot, nectarine, and peach, but they are far more abundant on Japanese varieties of plum.

The fruits of different varieties of the four kinds of hosts also show considerable variation in susceptibility. The nectarines suffer the greatest injury, the fruits of all the varieties of this host in Missouri being so badly cracked that they are usually destroyed by the various rot-producing organisms while still green. The effects of the disease on the fruits of Japanese plums, especially Abundance and Burbank, are nearly as severe as on the nectarines. The greater proportion of the fruits are badly distorted and cracked and the small number that are not rotted before they ripen are so badly injured that they are worthless for market. As a rule, apricot fruits are injured to a less extent than those of the nectarine or plum, but the variety Royal is severely affected. Though the fruits of some varieties of peaches, particularly Elberta, are severely injured, they are as a rule less badly disfigured than are the fruits of the nectarine or the Japanese varieties of plum (Fig. 63c).

In addition to this variation in susceptibility of the different varieties, there is also considerable variation in the amount of injury to the fruits of a given variety during different seasons. The real significance of these latter variations is not always easy to explain, but in most cases the age of the fruit and the weather conditions determine largely the percentage of infection.

In table 1 is given a list of the apricot, nectarine, peach, and plum trees in the variety orchard of the Missouri State Fruit Experiment Station, showing the nature and degree of susceptibility of the different varieties. These figures represent the average record for the year 1909. An estimate of the percentage of infection on leaves, twigs, and fruit was made by passing through the orchard, estimating and recording the injury. After the estimates had been made several trees in different parts of the orchard were carefully examined and the actual percentage of infection was obtained by counting the diseased leaves, twigs, and fruits. The difference found between the actual and the estimated percentages of infection

formed the basis for correction of all the varietal estimates. Three estimates were made in the course of the summer, the first in the middle of July, the second August 5 to 7, and the third September 26 to 29. The average result of the three records is given here as the record for the year.

TABLE 1. Relative Susceptibility of Different Varieties of Apricot, Nectarine, Peach, and Plum to Bacterium Pruni*

Apricot	
Bread, 40-30-30-f	Russian, 30-10-?-a
Moorpark, 40-20-0-f	Superb, 20-15-0-p
Peach, 75-30-0-a	Sweet Russian, 40-20-30-p
Nectarine	
Coosa, 45-15-100-a	Stanwick, 65-15-100-a
Munson's Cling, 50-8-85-a	Victoria, 60-10-100-a
New White, 58-8-100-p	
Peach	
Alexander, 25-15-5-p	Bokhara, 0-10-40-n
Alice Hampton, 20-15-35-p	Bonanza, 45-15-60-p
Alton, 40-20-80-a	Brandywine, 6-13-40-f
Amsden June, 8-5-25-f	Bray's Rareripe, 25-15-30-f
Arkansas Beauty, 35-15-50-a	Brett (Mrs. Brett), 20-30-30-a
Arkansas Mammoth, 50-10-50-f	Brigdon, 40-10-20-a
Arkansas Traveler, 40-10-0-a	Briggs (Briggs' May), 18-18-40-f
Arnett, 55-10-?-p	Bronson, 30-15-25-a
Arnett No. 6, 65-5-?-a	Burke, 20-10-35-p
Athens, 40-3-30-a	Carman, 60-0-30-p
Banner, 15-8-35-n	Carpenter (Carpenter Cling), 35-5-50-a
Barber, 8-5-0-f	Chairs (Chairs' Choice), 30-20-35-a
Barnard Early, 35-10-60-a	Champion, 60-0-30-p
Barnes, 5-3-0-f	Champion Yellow, 15-5-30-f
Beauty, 30-10-50-a	Charlotte (Early Charlotte), 35-10-?-p
Belle (Belle of Georgia), 15-3-25-a	Cherokee. 25-20-45-a
Bell's October, 20-10-25-n	Chili (Hills' Chili), 20-10-30-p
Bequette Cling, 23-3-45-p	Chilow, 25-40-25-p
Bequette Free, 40-10-70-a	Chinese Cling, 45-15-30-a
Bernice, 35-10-25-f	Chinese Free, 45-5-55-a
Bilyeu, 60-10-100-a	Christiana, 30-5-25-a
Bishop, 18-18-0-f	Cloves, 43-3-50-p
Blanchard, 55-10-45-a	Cobler, 25-15-20-p
Blood Cling, 45-10-0-p	Coleman, 20-10-30-p
Blood Free, 50-10-30-p	Collridge Favorite, 30-10-30-a
Blood Leaf, 55-5-45-a	Columbia, 35-15-40-a

*The first number following the name of the variety indicates the percentage of infected leaves; the second, the percentage of defoliation; the third, the percentage of infected fruit ("?" in the third place indicates that the tree bore no fruit). The letter in the fourth place indicates the number of twig cankers observed: a, abundant; p, plentiful; f, few; n, none. The letter in the fifth place (in the plum varieties) indicates the amount of injury due to trunk and limb cankers: e, extreme injury causing the death of the trees; m, marked injury; s, slight injury; n, no injury.

Peach (*continued*)

Conkling, 13–8–0–f
Connecticut, 43–3–60–p
Connet (Connet's Early), 15–10–60–f
Cora, 80–8–10–a
Crosby, 13–3–0–f
Crothers, 60–0–100–a
Davenshire, 40–20–0–a
Davidson, 35–20–50–p
Dawson's Early, 25–2–0–f
Delaware, 45–5–60–f
Deming (Deming's September), 60–10–40–a
Denton, 55–15–45–a
Dewey (Admiral Dewey), 20–10–0–p
Diamond, 50–20–30–a
Dover, 45–5–70–a
Early Barnard, 10–20–0–n
Early Crawford, 10–5–25–f
Early Heath, 35–5–25–p
Early Michigan, 30–5–80–a
Early Rivers, 30–15–40–f
Early York, 40–10–50–a
Ede (Captain Ede), 15–10–25–p
Edgemont Beauty, 11–5–25–p
Elberta, 80–30–45–a
Elberta Cling, 60–10–53–a
Eldred, 65–15–35–a
Emma, 50–15–50–a
Engle (Engle's Mammoth), 15–10–0–f
Etna, 20–10–25–p
Eureka, 45–10–55–a
Family Favorite, 80–10–70–p
Fischer, 65–5–100–p
Fitzgerald, 35–10–35–a
Flatters St. John, 65–5–80–a
Flemer's Cling, 65–5–98–a
Flewellen, 35–5–33–a
Floyd, 50–10–40–a
Ford's No. 1, 50–0–70–p
Ford's White, 40–10–25–f
Foster, 30–20–30–p
Fox (Fox Seedling), 18–8–35–a
Frances, 30–10–50–a
Froth's Early, 65–15–55–a
Future Great, 20–10–25–p
Garfield, 13–8–35–p
Geary's Hold-on, 28–8–25–p
General Taylor, 5–5–95–p
Gilman's Favorite, 50–10–45–a
Globe, 15–10–50–p
Gold Drop, 21–10–60–p
Gold Dust, 30–75–30–p
Golden Gate, 50–20–?–a
Gold Medal, 40–10–30–a
Gold Mine, 30–10–35–p
Gordon, 20–15–30–f
Grand Reporter, 55–15–50–a
Hale Early, 38–8–40–p
Heand's Beauty, 60–10–45–a
Heath (Heath Cling), 60–20–60–a
Heath Free, 60–20–25–a
Henrietta, 8–5–40–f
Hiley, 26–1–40–p
Hill's Madeira, 25–5–40–p
Hobb's Late, 15–10–22–f
Hobson, 30–25–?–a
Holderbaum, 20–5–25–f
Honi Chirf, 35–10–30–p
Hoover's Heath, 20–10–10–n
Horton's River, 45–15–70–p
Hughes I. X. L., 30–10–0–p
Hyde's Yellow, 20–5–20–f
Hynes (Hynes' Surprise), 20–10–30–f
Indian Blood Cling, 10–10–0–n
Indian Blood Free, 50–10–40–a
Ingold (Lady Ingold), 30–20–90–a
Japan Blood, 55–5–0–a
Jaques (Jacques' Rareripe), 15–15–25–f
Jennie Worthern, 35–10–30–a
Juno, 45–5–30–a
Kalamazoo, 10–8–0–f
Kerr (Jessie Kerr), 25–10–0–f
Krummel's October, 20–10–45–p
Late Crawford, 40–10–40–a
Late Elberta, 60–15–35–a
Laure Cling, 35–5–30–a
Lemon Cling, 12–10–0–f
Lewis, 0–10–50–n
Lodge, 40–10–60–a
Lola (Miss Lola), 25–10–40–f
Lorentz, 33–8–0–p
Louise (Early Louise), 35–15–0–a
Lovell No. 3, 50–0–?–a
McCallister, 20–15–?–f
McIntosh, 13–8–0–p
Madison County Mammoth, 40–10–70–a
Magnum Bonum, 35–30–25–a
Mamie Ross, 20–10–40–a
Mammoth Cling, 75–15–50–a
Marshall, 30–10–30–p
Mathews (Mathews' Beauty), 50–20–50–a
Mena, 40–10–?–a
Michigan, 10–5–0–n
Mid September, 23–8–25–p
Mint's Free, 30–20–80–p
Mixon Late, 75–5–30–a
Moore's Favorite, 20–15–50–a
Morris Late White, 50–10–30–p
Mountain Rose, 25–15–70–p

Peach (*concluded*)

Muir, 25–15–30–a
Munson's Cling, 65–15–100–a
Munson's Free, 60–10–70–a
Nanticoke, 23–8–30–f
Nelson's No. 5, 40–10–45–a
New Prolific, 10–15–25–f
Niagara, 45–5–40–p
Nicholson's Smock, 40–10–40–p
October Free, 50–10–33–a
Olden No. 1, 40–10–25–p
Olden No. 3, 50–10–100–a
Oldmixon Cling, 55–15–30–a
Oldmixon Free, 50–20–35–a
Oldmixon Improved, 30–15–45–p
Orange Cling, 40–20–35–p
Oriole, 30–3–55–p
Oritz, 28–18–40–a
Oscar, 63–8–70–a
Ozark Queen, 20–20–40–p
Pallas, 43–3–70–a
Pearce's Yellow, 30–10–0–p
Peento, 5–5–?–n
Pendleton, 40–10–25–a
Perry's Red Cling, 35–15–?–p
Plaut, 50–10–35–a
Pond's Seedling, 70–10–40–a
Pool's Favorite, 8–3–0–f
Queen, 40–20–50–p
Rasin Cling, 35–25–60–p
Ray, 20–5–30–p
Red Heath, 35–5–25–a
Red River, 60–15–30–a
Reeves Yellow, 20–15–0–f
Reynolds, 18–8–25–f
Ringgold, 40–10–40–p
Rivers, 58–8–25–a
Robert, 50–20–30–a
Rodgers, 20–5–45–p
Rose of Baltimore, 48–8–30–a
Rush's Favorite, 30–10–65–a
Russell, 23–20–20–n
St. John, 50–20–80–a
Salway, 15–15–35–f
Schofield, 60–0–40–a
Scott's Nonpareil, 65–15–40–a
Sea Eagle, 30–10–30–f
Sea Eagle Improved, 25–10–30–f
Shipler, 42–15–60–a
Shoemaker, 20–2–0–n
Smock (Smock's Free), 50–20–50–a
Sneed, 70–25–40–a
Snow, 35–10–25–a
Snow Free, 30–5–45–p
Snow's Orange, 23–10–0–n
Springfield, 50–10–40–p
Steadley, 30–10–35–p
Stevens, 60–10–35–a
Stevens Late, 20–20–40–f
Stinson, 65–15–65–a
Strout's Early, 15–10–?–f
Stump, 15–10–40–p
Success, 30–10–20–p
Summer Snow Cling, 40–10–55–a
Superb, 40–20–40–p
Sussex's Late, 35–5–45–p
Sylphide, 33–13–23–p
Texas (Texas King), 10–5–65–f
Thurber, 15–3–30–f
Tillotson (Early Tillotson), 10–12–0–n
Toledo (Early Toledo), 35–5–0–p
Topaz, 15–15–50–a
Tornado, 30–10–60–p
Trebout, 50–20–70–a
Van Buren, 30–3–?–p
Waddell, 60–10–45–a
Wager, 30–15–25–n
Walker (Walker's Variegated Free), 20–15–30–p
Ward's Late, 65–15–40–a
Washington Cling, 60–10–50–a
Waterloo, 20–0–40–p
Webb's Golden, 50–5–70–f
Wheatland, 40–10–?–a
Wheeler's Late, 75–5–25–a
Wilkins' Cling, 38–8–45–a
Willett, 50–15–30–a
Williams' Favorite, 40–10–23–p
Wilson's No. 14, 45–5–?–p
Wonderful, 35–15–0–n
Worth, 55–15–40–a
Wright, 5–3–30–n
Yellow Rareripe, 25–15–0–f

Plum

Abundance, 100–60–100–a–e
America, 40–20–20–p–s
American Eagle, 55–15–10–a–e
Apple, 90–40–?–a–m
Arkansas (Arkansas Lombard), 0–0–0–n–n
Assiniboia, 55–20–?–p–n
Best of All, 45–15–0–a–n
Broadshow, 0–0–?–n–n
Burbank, 100–60–100–a–e
Case Gold Drop, 0–0–?–n–n

Plum (*concluded*)

Chabot, 85–15–100–a–m
Clifford, 0–0–10–n–n
Cumberland, 20–0–0–a–m
Downing (Charles Downing), 55–20–0–n–m
Diamond, 0–0–?–n–n
Douglass, 80–20–0–a–m
Damson (Blue Damson), 0–0–?–n–n
Elapa, 55–20–0–n–n
Funk, 0–0–?–n–m
Gonzales, 95–30–?–a–m
Grand Duke, 0–0–?–n–n
Guthrie Topaz (Topaz), 63–25–?–n–n
Hale, 90–35–?–a–m
Hattankio (Hytankio), 50–15–10–a–m
Hawkeye, 50–15–0–p–n
Hungarian Prune, 0–0–?–p–n
Italian Prune, 0–0–0–n–n
Jefferson, 0–0–?–n–n
Jones Special, 75–25–30–n–n
Kerr, 60–25–?–a–m
Krap, 55–33–0–p–n
Kroh (Poole's Pride), 40–20–10–f–m
Lacy, 100–45–?–n–n
Lombard, 0–0–?–n–n
Maryland, 0–0–0–n–n
Milton, 0–0–0–n–n
Monarch, 50–20–?–p–n
Newman, 40–20–10–f–n
October (October Purple), 85–40–?–a–m
Ogon, 95–30–30–a–e
Orleans (Smith's Orleans), 0–0–?–n–n
Owanka, 55–15–?–n–n
Peter's Gage, 0–0–?–n–n
Pond (Hungarian Prune), 0–0–?–p–n
Pride (Shipper's Pride), 30–12–?–f–n
Purple Leaf, 90–35–?–a–m
Quaker, 45–15–50–p–m
Reagan, 55–25–0–n–n
Red Goose, 40–20–?–n–m
Red June, 95–25–100–a–e
Red Nagate, 100–50–?–a–m
Red October, 55–10–0–a–m
Reine Claude, 40–8–?–p–n
Robinson, 40–15–100–n–m
St. Martin (Coe's Late Red), 0–0–?–n–n
Shropshire (Shropshire Damson), 0–0–?–n–n
Sophie, 40–10–10–f–n
Stella, 95–55–?–p–n
Tokeya, 40–10–?–n–n
Wakapa, 55–15–?–n–n
Ward October, 40–10–20–p–m
Ward October Red, 45–15–0–a–m
Wastesa, 75–35–?–p–n
Whitaker, 0–0–0–n–m
Whiting, 0–0–?–n–m
Wildgoose, 40–10–0–n–m
Willard, 100–40–?–p–e
Winnipeg, 55–25–?–f–s
Wohanka, 50–25–?–n–n
Yellow Egg, 0–0–?–n–n
Yosemite, 90–30–10–a–e
Zekanta, 48–15–?–n–n

CONTROL

Observations and experiments in control were made principally with peaches and plums, as only a few varieties of apricots and nectarines were available for experimental work. This phase of the subject may be discussed under four heads: exclusion, eradication, protection, and immunization.

EXCLUSION

In budding, the greatest care should be exercised in selecting material only from trees known to be free from the organism. Even though the twigs are free from cankers, the organism may be transferred to the healthy stock through infected buds. Laboratory and field experiments made at the Missouri State Fruit Experiment Station show that it is impossible to determine from the external appearance of the bud whether it is infected.

In preparing to set out an orchard, great care should be used in ordering the trees. Purchases should be made only from reliable nurserymen, and, if possible, the nursery should be visited and the trees inspected in the fall, while they are still in full leaf, in order to make sure that the foliage is free from shot-hole condition and the twigs are free from cankers. If this is impossible, the trees should be carefully examined for black cankers in the spring, before they are set out. The disease is usually more easily detected in fall than in spring. All infected trees should be rejected.

Since the organism is readily carried from one tree to another, the location of a young orchard or nursery in relation to old, diseased trees or orchards is of considerable importance. The writer has frequently observed old orchards which served as centers of inoculum for young trees.

In 1906 a tract of one hundred and sixty acres of new land near Koshkonong, Missouri, which bordered an old peach orchard on the south, was set with two-years-old Elberta peach trees. During the first year the foliage on the trees in the first fifteen rows became more or less diseased, but during the second year the disease advanced more rapidly and the foliage on trees in the two hundred and fifty rows next to the old orchard became involved. The trees beyond this, however, were normal and were making satisfactory growth. At the end of the third year nearly every tree in the entire orchard was diseased. Those in the first fifty rows bordering the old orchard contained more twig cankers than did those in any other part.

ERADICATION

After the disease has once become established, the chief point of attack is, of course, the cankers on twigs, limbs, and trunks of the trees, since these wounds not only serve to carry the organism through the winter but also in many cases tide it over unfavorable periods in summer. Careful pruning not only removes many of the twig cankers — and very often the cankers near the tips of the twigs contain the greatest numbers of bacteria — but also serves to stimulate new growth which often shows considerable resistance to the attacks of the organism. It is of course impossible to remove all the twig cankers in a crop season. But in an off year, when the fruit buds have all been winterkilled, the twig cankers on the old trees can be removed by cutting back the limbs to one-fourth of their entire length and carefully trimming out all the

one- and two-years-old twigs from the center of the trees. Lesions on the limbs and trunks soon form rough, open cankers and can easily be found. Such wounds must also be cut out, or, if this is impossible, the diseased tissue must be completely removed by cutting around the canker well into the healthy part of the limb or the trunk. In every case the wound should be thoroughly disinfected with corrosive sublimate solution, one part to one thousand parts of water. The organism can usually be eliminated in this way on the apricot, the nectarine, and the peach. In the case of the plum, however, especially on the Japanese varieties where the organism has invaded the large limbs and the trunk, it is practically impossible to save the tree.

In 1907 the peach trees in the Missouri State Fruit Experiment Station variety orchard were heavily pruned. All the limbs were cut back one-fourth of their length. One hundred and thirty Elberta trees of the same age were not severely pruned but were treated in every other way as the other trees. During the fall the foliage on the pruned trees was of a better color and more nearly free from disease than that on the unpruned trees. In 1908 little or no injury was observed on the pruned trees, while foliage on all unpruned Elberta trees was more or less diseased. Twenty per cent of the leaves finally fell, and twig cankers also were plentiful. Chandler,[4] of the University of Missouri, has also observed in his work that severe pruning tends to make the trees more nearly free from the shot-hole disease.

PROTECTION

Spraying

Since bordeaux mixture has been used successfully in controlling various plant diseases, and lime-sulfur has been used also with more or less success, a number of experiments were undertaken in order to determine the effectiveness of these mixtures in controlling this organism.

In 1908, thirty-two eight-years-old Elberta peach trees were sprayed seven times with bordeaux mixture, and twelve were used as checks. The first application was made with the 6-4-50 formula on March 12, just before the fruit buds opened. The other six applications were made with the 2-9-50 formula after the leaves had unfolded; the first of these was made on April 21, and the others followed at intervals of from twelve to fifteen

[4] Chandler, W. H., in a letter dated September 26, 1912.

days. On August 12, the leaves, the twigs, and the fruit on the sprayed trees were free from disease. The fruit was of excellent color and quality, but there was sixty-one per cent less fruit on these trees than on the checks. The leaves on the checks were badly shot-holed and about ten per cent of them had fallen. The twigs also contained many blackened cankers. Sixty-three per cent of the fruit was infected.

In the same year, twenty-nine eight-years-old Elberta peach trees were sprayed seven times with lime-sulfur. Eleven trees were used as checks. The first application was made with the standard 15-15-50 formula on March 12, just before the buds opened. The other six applications were made with self-boiled lime-sulfur, 12-8-50 formula, after the leaves had opened; the first of these was made on April 21, and the others followed at intervals of from twelve to fifteen days. On August 12 the foliage on the sprayed trees was more or less dotted with diseased spots. The twigs also showed a few black cankers. Fifty-two per cent of the fruit contained many small bacterial wounds, but otherwise it was in good condition (Fig. 64). The yield was reduced twenty per cent. On the check trees the foliage was badly injured and ten per cent of the leaves had fallen. The twigs also showed many cankers. Sixty-three per cent of the fruit was diseased and cracked, its market value being considerably reduced.

In 1909, twenty-two nine-years-old Elberta peach trees were sprayed four times with peach bordeaux mixture, 2-9-50 formula. Twelve trees were used as checks. In 1908 curculio punctures made it difficult to determine the exact extent of injury due to the attack of this organism, and therefore in all the spraying experiments in 1909 arsenate of lead was added to the mixture used in the first two applications. The poison was added at the rate of two pounds to fifty gallons of the spray mixture. The first application was made about seven days after the petals had fallen, and the three others followed at intervals of four weeks. On August 8, as far as could be observed, the leaves, the twigs, and the fruit were free from disease. The foliage on the check trees was badly injured, and fifteen per cent of the leaves had fallen. The twigs contained many black cankers. Sixty-five per cent of the fruit was injured, and most of this was worthless.

In 1909, twenty-four nine-years-old Elberta peach trees were sprayed four times with self-boiled lime-sulfur, 12–8–50 formula. Arsenate of lead was added to the first two applications at the rate of two pounds of the

poison to fifty gallons of the mixture. The first application was made about seven days after the petals had fallen, and the three others followed at intervals of four weeks. On August 8 only a few spots were observed on the leaves, and the twigs were apparently free from cankers, but fifteen per cent of the fruit was infected. The foliage on the check trees was badly injured, and fifteen per cent of the leaves had fallen. Many of the twigs were badly cankered. Sixty-three per cent of the fruit was infected, and most of this was worthless.

Apparently the arsenate of lead improved the effectiveness of the self-boiled lime-sulfur solution. It is quite probable, however, that the beneficial results obtained from the addition of arsenate of lead are due rather to the control of insects which serve as agents of dissemination than to the improvement of the mixture as a fungicide. Laboratory tests show that arsenate of lead used at the rate of two and one-half pounds to fifty gallons of water has very little influence on the growth of this organism.

From these and other experiments, it is evident that bordeaux mixture will control the disease. But the foliage of the trees, especially in the case of peach and nectarine, is extremely sensitive to the action of copper, and in some cases the trees are defoliated even when the copper is used at the rate of one-half pound of copper sulfate to nine pounds of lime and fifty gallons of water. Self-boiled lime-sulfur alone is much less effective, and in all the writer's experiments it failed to control the disease; but when two pounds of arsenate of lead were added to fifty gallons of the mixture it became much more effective.

Cultivation

A tract of about two hundred acres of new land at Koshkonong, Missouri, was set in 1906 with two-years-old Elberta peach trees which were more or less infected with the organism. Strips about four feet wide were plowed across the field and trees were set on the plowed land. The orchard was fairly well cultivated during the first three years. The organism gradually spread from the diseased to the healthy trees, and at the end of the third year every tree in the entire tract was more or less infected. Many of the trees were stunted and some of them finally died. Their death, however, could not be attributed directly to the work of this organism, but was apparently due to a combination of winter injury of the roots, premature defoliation due to the work of the bacteria, and, finally, the

invasion of the roots by one of the root rot organisms. The trees of this orchard were uneven and produced very little fruit.

In the same year another tract of about one hundred acres of new land was planted with two-years-old Elberta trees brought from the same nursery. In this case the ground had been thoroughly prepared and the orchard was carefully cultivated during the following three years. A number of infected trees were observed in different parts of this orchard in the first year, but the disease spread very little and by the end of the third year all traces of disease had disappeared. The trees developed uniformly and produced large crops of excellent, clean fruit.

Diseased trees that have been properly cultivated invariably hold their leaves longer and resist the influence of the organism much better than do poorly cultivated trees. The general vigor of the host plays an important part in controlling the disease. Trees standing in thin, poor soil invariably suffer more severely than do those standing in more fertile places. Trees that yield abundantly are less resistant than those that produce little or no fruit. The foliage of infected trees that yield full crops in two consecutive years usually falls prematurely if the trees are not liberally fertilized and well cultivated.

In the spring of 1907 the peach trees in the Missouri State Fruit Experiment Station variety orchard were cut back severely, and about the middle of May complete fertilizer at the rate of 800 pounds to the acre was applied to the soil on one-half of the orchard. The same amount was applied also to an acre of Elberta peach trees of the same age which had not been cut back. Both the variety orchard and the Elberta orchard were finally planted in cowpeas. On September 1 the foliage on the trees that had been cut back and fertilized was in good condition and no premature defoliation was observed. The foliage on the Elberta trees, which had been fertilized and not cut back, was in fair condition, but from two to five per cent of the leaves had fallen. The foliage of the trees that had been cut back and not fertilized was more or less injured and from ten to twenty per cent of the leaves had fallen. The most striking results, however, appeared in September, 1908. The trees in the fertilized and cut-back block were practically free from disease. The foliage on the Elberta trees, which had been fertilized and not cut back, was more or less diseased, twenty per cent of the leaves had fallen, and many of the twigs contained black cankers. The foliage on the block of trees which

had been cut back and not fertilized was much improved, not over two or three per cent of the leaves had fallen, and the twigs on very few of the trees contained cankers.

Chandler,[5] in a series of commercial fertilizer experiments conducted at Brandsville, Missouri, from 1910 to 1912, also has shown that the organism can be controlled to a large extent by the use of fertilizer. He obtained excellent results in using from 700 to 800 pounds of complete fertilizer per acre on mature trees and from 300 to 400 pounds on trees from two to three years old. Applications were made once a year in early spring or in June. Those made in June apparently gave better results than those made in spring. Chandler's results show that nitrate of soda is the essential element for controlling the disease. All plots that received nitrate of soda, whether alone or in combination with either potassium chloride or acid phosphate or both, showed very great resistance to the disease, but the plots receiving only potassium or phosphorus or both did not show any increased resistance. In the plots treated with nitrate of soda a few leaves were affected, yet very few fell as the result of the disease and the foliage had a healthy color. In some cases the trees of the check plot and those treated with potassium chloride and acid phosphate lost as high as fifty per cent of their leaves.

An application of manure well worked into the soil gives excellent results and in some cases the improved condition of the trees is more permanent than when commercial fertilizer alone is used. Good results have been obtained by seeding down the orchard permanently to red clover after a liberal application of manure. The clover is cut from time to time and allowed to rot under the trees. This practice, however, has disadvantages and cannot be recommended for general use. Very good results have been obtained also by following an application of manure with cowpeas. The tops are not cut but are allowed to stand until killed by frost, and the following spring the dead material is carefully worked into the soil. After the first year commercial fertilizers and cowpeas are used, but if the trees show marked improvement nitrate of soda is omitted from the fertilizer, since the cowpeas as a rule furnish sufficient nitrogen. This method gives good results. The peas, however, furnish an abundant food supply for mice, which are likely to injure the trees during the winter.

[5] Chandler, W. H., in a letter to the writer dated September 26, 1912, containing a summary of some of his commercial fertilizer experiments with peach trees. A detailed account of the experiments will finally be published by the Missouri Experiment Station, Columbia, Missouri.

IMMUNIZATION

No doubt much can be accomplished in the way of resistance by crossing the less resistant with the more resistant varieties. This is especially true in the case of plums.

RECOMMENDATIONS FOR CONTROL

Since the organism is spread largely in the nursery, great care should be exercised in selecting trees for planting. Stock should be bought only from reliable nurserymen, who should be required to guarantee the trees to be free from the disease. A single diseased tree may cause serious loss after the trees are set out.

Old, neglected, budded apricot, nectarine, peach, and plum trees, especially plum, usually harbor the organism and become a menace to young orchard trees. All such trees should be cut down before the young trees are set out.

The ground must be thoroughly plowed before the young trees are set, and about one pound of a complete fertilizer should be worked into the soil about the tree while it is being set. Too much care cannot be given to the cultivation of an orchard, especially during the first two or three years.

Where the organism has become thoroughly established, systematic pruning, cutting out, and careful removing of all the diseased tissue from the cankers on the limbs and the trunks of the trees will eliminate the source of infection to a large extent. Complete eradication on old trees (seven or eight years old), however, can be accomplished only by pruning the trees. Pruning not only tends to eliminate the source of infection, but also serves to stimulate new growth which is more resistant to the disease.

Where the trees have been heavily pruned, a thorough application of bordeaux mixture (4 pounds of copper sulfate, 4 pounds of lump lime, and 50 gallons of water) just before the buds open will be of considerable assistance in controlling the disease on the fruit, especially if this application is followed by two or three applications of arsenate of lead ($2\frac{1}{2}$ pounds of arsenate of lead, 4 pounds of lump lime, and 50 gallons of water) to control the curculio and other insects, which aid materially in disseminating the organism. The first application of arsenate of lead should be made just as the shucks slip; the second, two weeks later; and the third, about two weeks after the second.

The older trees that are in good condition are as a rule not seriously injured by the disease. Thorough cultivation of an orchard and the use of fertilizers are absolutely essential. Complete fertilizer, at the rate of about 600 pounds to the acre in early spring for mature trees and from 150 to 300 pounds for young trees, gives very good results. In crop seasons a second application of about 250 to 300 pounds of the fertilizer should be made in June; the amount of nitrate of soda in this application should be reduced by about one-half. A liberal application of stable manure in the spring, well worked into the soil, will also give excellent results. Close attention to pruning and to the chemical and physical conditions of the soil will practically control this disease.

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